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THE SMALL OBSERVATORY AND ITS DESIGN

By H. BOYD BRYDON

"A successful design is a bundle of fortunate compromises between the great number of conflicting interests."—W. W. CAMPBELL, *Stellar Motions*, p. 44.

I

ALTHOUGH good work can be done in the open air, standing in even a moderate wind, especially in winter, can be very unpleasant; and an observatory, be it ever so humble, offers many advantages. A 6-in. reflector is easily stored indoors when not in use, but the time required to set up and adjust and to dismount and take indoors is not an inducement to observation after a busy day, and with larger and heavier instruments the labour becomes burdensome.

In an observatory the telescope is permanently mounted in correct orientation on a solid base, the various accessories, charts, eyepieces, notebooks, etc., are at hand and ready for work without loss of time, while the telescope and the observer are screened from stray light and protected from wind. A table with a drawer or two in it, a couple of chairs, a shelf for books and sufficient light, red for choice, with conveniently placed switches if electric power is available, add much to the convenience and usefulness of the small observatory.

It is hoped that these notes and drawings may help the amateur astronomer to provide himself with an adequate workshop at a cost little greater than that of a well-built garage.

Factors affecting general design and various methods of construction are illustrated and discussed, and plans are given for observations of two general types: (1) round or polygonal buildings for 6-in. to 8-in, telescopes, and (2) rectangular buildings for 6-in. to

8-in. and for 10-in. to 12-in. telescopes. The modifications desirable in the larger of the rectangular buildings when it is to house an instrument having a stationary eyepiece are also discussed.

Although not involving great outlay, the possibility that a change of residence might necessitate its abandonment has deterred

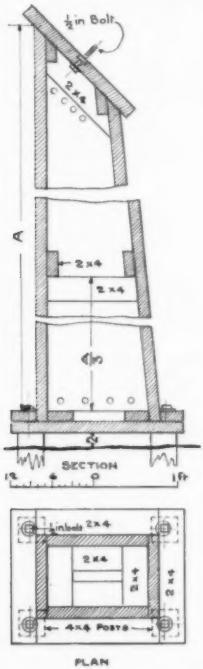

Fig. 1. Built-up Wooden Pier.

many from building an observatory. The designs here published have been made with this in view, and methods of construction are indicated which enable the buildings to be taken apart and re-erected without appreciable damage and at little expense. Even the pier need not be a total loss. A satisfactory pier for a 6-in. to 8-in. telescope can be made of two 6-in. by 6-in. or 8-in. by 8-in. squares

bolted together and planted solidly in the ground. For larger instruments a pier made of a shell of 2-in. boards, preferably tongued-and-grooved, thoroughly braced and put together with stout screws, say No. 12, and filled with clean stones or, failing that, with well-screened and washed gravel, is easily removable, and to all intents and purposes will serve for many years as well as a concrete pier if the following precautions are taken: each separate piece of wood should receive two coats of white lead and linseed oil paint, well brushed in and followed by a third coat applied to all surfaces to be in contact as the pieces are put together;[1] a number of 1-in. to 1½-in. holes should be bored just above ground level and near the top of the pier for ventilation, the stones or gravel should be dry, free from clay and sand, and evenly packed into the shell. The pier should be bolted to four substantial posts, say 4-in. by 4-in., well tarred, set solidly into the ground and cut off about two inches above the surface. Such a pier is shown in Fig. 1. It looks much heavier in the drawing than it does when built. The top may be inclined as shown or horizontal to suit the mounting. The ½-in. bolt in the centre of the top is useful when setting the mounting into the meridian.

Buildings such as these are very light compared with the surface they expose to the wind. In all cases the sills of the walls should be bolted to the foundation and hooks should be fitted to secure the roof to the walls and shutter to the roof when not in use, otherwise serious damage is almost certain to be caused by high wind.

While the observatory is being built, the services of a skilled carpenter who can read and follow drawings correctly will be found most valuable, particularly in framing the roof. For those, however, who, having the skill although lacking experience, may decide to do without this aid, methods of construction are given in considerable detail. If the old adage, "Measure twice and cut once" is kept constantly in mind, each step checked as the work proceeds and nothing "scamped", a successful job should result. Templets are of great assistance and should always be used when opportunity serves.

[1]All surfaces to be in permanent contact should be painted, and put together while the paint is wet, to keep out moisture and retard decay.

II

The small observatory has developed along two general lines in the treatment of the roof:

(1) The removable or "run-off" roof.

(2) The rotatable roof having an opening closed by a shutter.

1. Observatories of the first class serve as sheds for the protection of the instrument when not in use rather than as observatories in the usual sense of the term, although they are occasionally employed for that purpose. They consist of a rectangular enclosure covered by a roof which either rolls off in one piece on a horizontal runway carried on posts from the ground, as in Fig. 2, or in halves which roll off

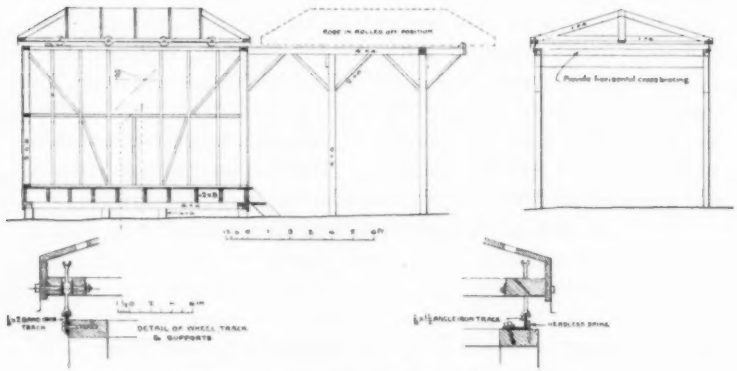

Fig. 2. Observatory with "Run-off" Roof.

independently on horizontal or inclined tracks projecting from opposite ends of the building.

As the roof is removed when observing, the upper part of the telescope and, if a Newtonian, of the observer also are practically in the open air, for the observatory is then only a tallish fence around the instrument over which the wind can (and does!) curl and shake the telescope, disturb loose papers and chill the observer. Except perhaps in warm climates or for very special conditions such buildings are undesirable as observatories.

2. The rotatable roof should be light for ease in turning but

strong enough to withstand any probable wind or snow-load that may come upon it, and capable of supporting safely at least two men so that it can be repainted and repaired as needed. Three forms are commonly used: the dome, the drum, and the Romsey. The last is a peaked or pyramidal roof, which was originated by the Rev. E. L. Berthon of folding boat fame, and inventor of the screw propeller for boats, who designed it for his observatory at Romsey, near Southampton, England.

Architecturally the classic dome is easily the most pleasing but it requires great nicety of construction, especially in framing the curved shutter and in the means for operating it.

Ease of construction, not beauty of form, has been the principal reason for the development of the drum and Romsey roofs. But, though not surmounted by an orthodox dome, the small observatory need not, and indeed should not, be the eyesore it too frequently is. It was a fine sense of the fitness of things that prompted Tycho Brahe to don court dress when he went to observe the stars.

Of the three types the drum is perhaps the simplest to build, but unless very carefully proportioned it has a rather clumsy look. It is improved by having a polygonal instead of circular plan.

The Romsey roof as usually built, with a flat shutter hinged to one side of the opening, presents a lop-sided appearance because the apex or ridge must be set well off centre to give access to the zenith. The construction shown below for the 12-in. observatory is an improvement in this respect. A worse feature, however, is that the hinged shutter has an annoying habit in a cross-wind of acting as a sail and swinging the roof around during an observation.

This difficulty was solved by Mr. A. Lloyd, F.R.A.S., by the simple expedient of removing the shutter bodily from his observatory when starting work. His observatory is strictly utilitarian and, to judge by the half-tone picture accompanying his description,[2] hardly beautiful; but it can be easily improved both aesthetically and practically and is a good example of a very inexpensive but useful observatory. Its general construction will be seen from Fig. 3, which was drawn after Mr. Lloyd's description, but with some changes in detail to simplify the building of it, and it is two

[2]A. Lloyd, F.R.A.S., "How to build your own Observatory", *English and Amateur Mechanics*, now *English Mechanics*, November, 1927.

feet less in diameter than the original. The walls are formed by eight light wooden frames which are bolted to the sills with $\frac{1}{2}$-in. carriage bolts. A laminated wall plate is spiked or bolted to the top members of the frames holding them securely in place and forming the bearing ring or track on which the roof rotates.

The walls as well as the roof of the original observatory were covered with "ruberoid" roofing supported by wire netting stretched over the completed framework.

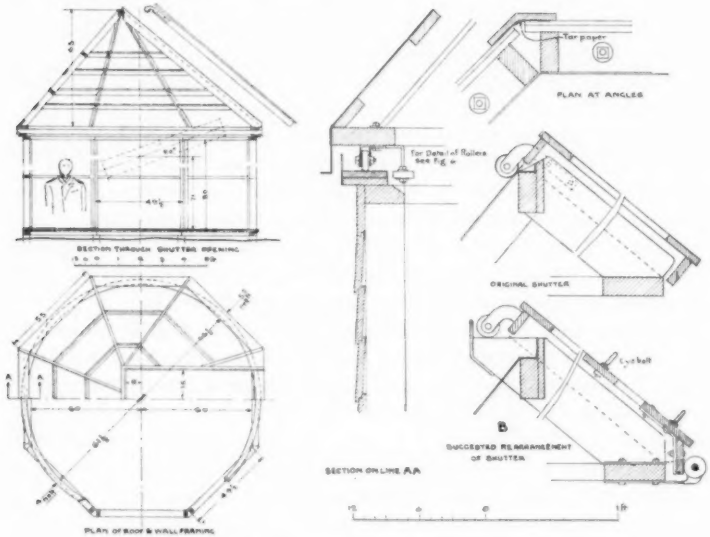

Fig. 3. Lloyd's Observatory with Removable Shutter.

The shutter, the feature of the design, is a loose fit over the raised edges of the opening and has a long roller extending across its upper end. It is operated as follows: To remove the shutter, standing inside the building, the lower end is lifted clear of the sides of the opening and held temporarily in that position by a rod placed across them. Then, from outside, using the rod as a fulcrum and bearing down on the lower end the upper end is raised to clear the top of the opening and the whole affair is rolled by hand down and

off the roof and laid aside. To replace, the roller is set across the opening and the shutter pushed upwards until the roller drops behind the top of the opening when the lower end is let down into place.

In the original observatory it was particularly easy to manipulate the shutter as described because the walls were only some 4ft. 3 in. high. Where the walls are made high enough for a doorway of usual proportions, the arrangement shown at *B* is suggested. It has the advantage that all the work of removal and replacement is done outside the building. A second roller fitted at the bottom of the opening carries the load during part of the process and serves as a stop when the shutter is in place. To remove the shutter, the lower end is raised clear of the bottom roller by a lifting rod slipped into the eye-bolts shown, the top roller acting as the fulcrum. As the shutter moves off, the load passes to the bottom roller which carries it until the shutter is clear of the opening. It is replaced by reversing the procedure.

If an observatory is to be built on the general lines of Mr. Lloyd's design, the following suggestions should receive attention:

(1) Increase the height of the walls to afford easier access. This, of course, involves increasing the height of the pier. In some cases, however, the advantage of low walls for observing at low altitudes has been retained without raising the telescope by setting the entrance doorway below the level of the observing floor and building inside steps between them. Even when a hinged flap is fitted over the opening in the floor for these steps the arrangement is unsafe, for in spite of precautions someone sometime will forget to lower the flap and a bad fall and serious injury may result. A place where persons are to move about in darkness should be free from all possible pitfalls.

(2) Fasten the sill members together with "halved" joints instead of butt joints, having iron splice plates top and bottom.

(3) Instead of wire netting and ruberoid or similar roofing material, cover the wall framing with shiplap laid as shown or with plain sawed 1×6-in. boards. Either looks well stained brown with the window and door trim painted white. If utility is the only consideration, corrugated iron can be used.

(4) Use ball-bearing roller-skate wheels attached to the roof plate instead of specially made wooden rollers attached to the wall plate (see Fig. 6).

(5) Use purlins or braces between the rafters as shown to take the pull of the wire netting on the roof instead of an iron tie rod across the shutter opening. However, this construction is not safe against a heavy snow-load. If a ruberoid or similar roofing is used the roof must be close boarded. Galvanized iron with purlins at the lapped joints and supported at the wide spans as shown in the figure will make a better and lighter roof.

(6) Also provide a window or two so that the observatory can be used in daytime.

(7) A firm floor preferably of wood, or cement if desired, sufficiently raised above the ground level to be dry.

(8) Shelves and racks for books, etc.

(9) A table or desk with a drawer in it.

An observatory of even simpler construction is shown in Fig. 4. There are no walls as such, simply a "teepee"-shaped roof built with 2×3-in. rafters framed at the top to a flat deck and at the bottom to an octagonal plate carried on ball-bearing roller-skate wheels. The framing is covered with No. 28 galvanized sheet iron laid with a 3-in lap. Where the sheets lap, 1×3-in. purlins are fitted between the rafters as nailing strips and serve to stiffen the framing.

There are two shutters: a short one, giving access to the zenith, rolling on the flat deck of the roof and operated from inside the observatory; and a removable one, reaching an altitude of about 64°, operated from outside. The removable shutter opening extends to the base plate of the roof and forms the doorway, a hinged "half-door" opening outwards being fitted to close the lower part.

To close the observatory the zenith shutter and the half-door are closed and bolted. Then from outside, the removable shutter is put up over the two projecting iron lugs and secured by two padlocks passed through holes in their ends.

The rotating part of this observatory will weigh about 700 pounds, but it will be found to move easily on the ball-bearing wheels.

In Fig. 4 the wood floor is shown carried on joists resting on sills and posts. If desired, the wood floor may be laid on "grounds", or a concrete floor may be used, the roof track being carefully levelled and grouted to the rough concrete and the cement floor finished to it. In either case as the roof plate, which is also the threshold of

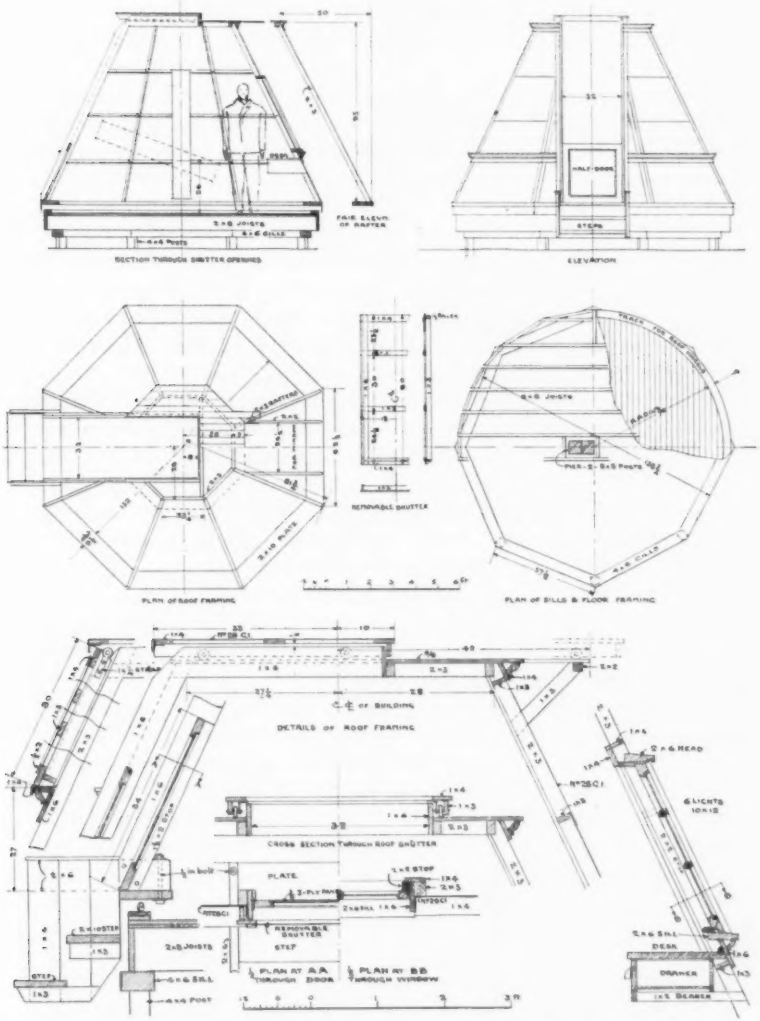

Fig. 4. Teepee Observatory and Details.

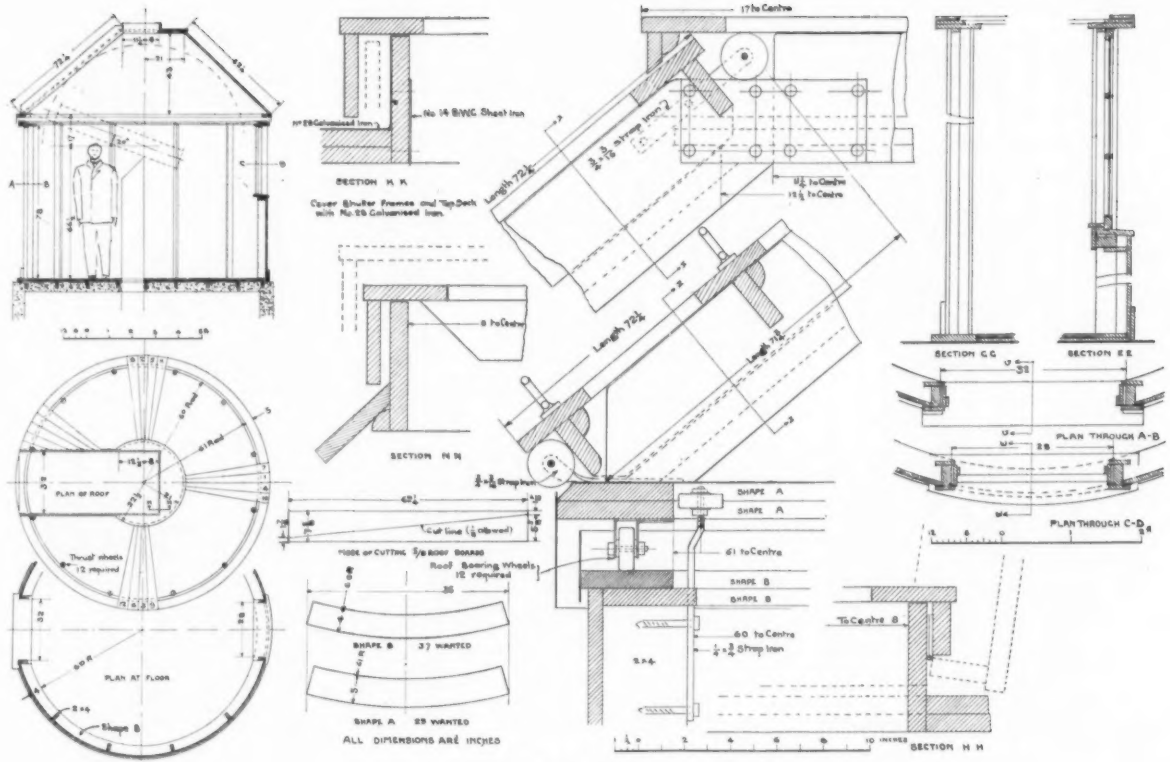

Fig. 5. Hodgkinson Observatory and Details.

the entrance, is within easy stepping height from the ground, the entrance steps shown, which are attached to the roof and turn with it, will not be needed.

A third observatory of this general type, based upon a design by Mr. H. Hodgkinson, of New Westminster, B.C., a member of our Society, is given by his kind permission in Fig. 5. Although requiring rather more accurate fitting together of the parts, this is perhaps the simplest of the three.

Any preferred construction can be used for the base, but, as shown in this figure, the observatory is built on a concrete base with the shiplap floor laid on "grounds". The work proceeds as follows: the ground is excavated for a few inches deep over the area of the floor and to a depth below frost line in the centre where the pier will be set; and for 5 or 6 inches wide around the edge of the concrete base, the forms placed and the "grounds", lengths of 2×3-in. are set with their tops at the level of the underside of the rough floor. The concrete is then poured and levelled off about half an inch below the tops of the grounds. The concrete may be: 1 part (volume) of portland cement, 3 parts clean sand, and 5 parts crushed stone or coke (coke breeze) or clinkers (not ashes), well mixed and not too wet. To prevent dampness and preserve the wooden floor from decay, give the concrete when dry a thorough coat of hot tar. The rough floor of shiplap is laid and the centre marked on a board firmly tacked across the centre (pier) form. Then, with a batten and two nails, one driven into that centre and with the other projecting about half an inch, scribe two circles on the shiplap, one with the outside radius of the roof plate, 66 inches, the other with the inside radius of the wall plate, 60 inches.

From the lumber mill get 25 pieces, $\frac{5}{8}$ or $\frac{3}{4}$-in. thick cut to the shape *A*, Fig. 5, 12 of which should be of hardwood as they will form the track for the roof wheels, and 37 pieces to shape *B*. Twelve pieces are required for each circle, the length allowing a little to be trimmed off the last piece in each layer to close the circle. The remaining pieces are used in forming the door opening and window-frame (see detail).

Now make two rings, each two layers thick, the joints staggered and the layers fastened together with $1\frac{1}{2}$-in. No. 8 screws, using not less than 10 screws to the piece. The ring for the roof plate is made

Fig. 5. Hodgkinson Observatory and Details.

to fit the outside scribed circle, using pieces of shape *A*. The other ring, for the wall plate, has the bottom layer of shape *B*, except for two pieces of *A* at the door and window openings and the top layer, of hardwood of shape *A*. Leave the wall plate in halves until the roof is built and out of the way.

Next make the top deck for the roof as shown of two layers of No. 1 cedar shiplap with the joints crossed for stiffness and well screwed together.

The roof is in the form of a truncated cone. There are no rafters. Cedar is used for lightness. The roof is most conveniently built on the shiplap floor, setting the roof plate to its scribed circle with the top deck secured at the correct height above it, its centre vertically over the centre of the floor. Fit the coamings, etc., for the shutter opening and brace firmly before proceeding to board in the roof. To insure the job being true, put on the boards in the order that they are numbered on the drawing and follow this order until finished. Smooth all rough or sharp edges and prime, stop and paint two coats the outside surfaces. The roof covering may be "Duroid" or equal prepared roofing or No. 28 galvanized iron. The shutters may be made later.

Raise up the roof and set it on a staging about 8 inches or so higher than the finished wall will be and centrally over the floor.

Next fasten one layer of pieces of shape *B* to the shiplap floor, fitting the inside scribed circle for a floor plate. Set the halves of the wall plate on the floor plate, make the remaining joints, raise it up to the roof plate and lash it there temporarily.

Now cut 12 pieces of 2×4-in., exactly to length and toe-nail them firmly to the floor plate, spaced as shown, flush with its outside edge and upright. Unlash the wall plate, lower it on to the uprights and spike or bolt it to each. Check the work. The centre of the wall plate should be vertically over the centre point of the floor and every upright should be vertical. Brace the completed framework securely and put on the V-joint wall covering. Now fit the two sets of rollers in place, lower the roof on to the wall plate, see that it rotates easily and secure it to the wall plate with stout hooks and eyes.

The zenith shutter is either hinged to the back of the opening, as in Fig. 5, or arranged as a sliding hatch as in the "Teepee" (Fig.

4). The inclined shutter is removable as already described and made to the details given in the figure. The rest of the work needs no description.

For reasons connected with certain special conditions, the roof of the original of this observatory was carried on grooved wheels of cast aluminium running on a band iron track secured to the edge of the wall plate. Such are not generally desirable, however. The free path of a rolling wheel lies in a plane at right angles to its axis. When, as in carrying an observatory roof, wheels are forced by means of flanges to move in a circular path, the change of direction

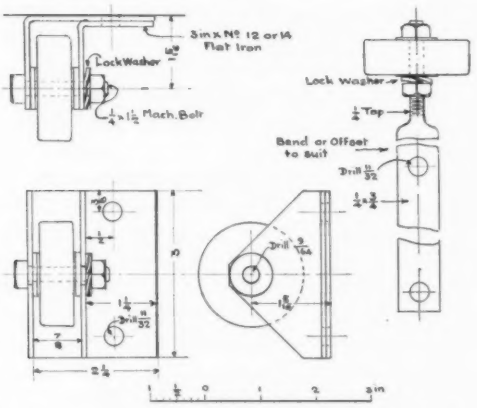

Fig. 6. Details of Wheel Arrangements for Rotary Roof.

is effected at the expense of greatly increased friction by the flanges grinding against the side of the rail or track. By using two sets of wheels, one running on a horizontal circular track to carry the load, and the other running on a vertical cylindrical track to guide the first set in its circular path, friction is reduced and flanges are not needed.

Roller skate wheels of the double ball-race type serve excellently. They are not subjected to the heavy shocks or loading of their usual service and they are inexpensive. Fig. 6 shows convenient ways of

adapting them to this use. Rigid base truck casters having ball-bearing wheels are also available.[3]

Comparison of these three observatories and the several methods of construction employed in them will prove interesting and suggestive. Doubtless all can be improved as all can be modified to suit local conditions and individual preferences. Preferred details in one may be used in another by making any adjustment required in dimensions. In all cases the telscope shown is an 8-inch Newtonian on a German mounting, and the space available is indicated by the figure of a man drawn in the sectional views.

(*To be concluded*)

[3]The ball-races should be thoroughly washed out with kerosene and filled with a good, heavy lubricating grease before being put in service.

THE FIFTY-EIGHTH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY

By R. M. Petrie

THE fifty-eighth meeting of the American Astronomical Society was held at Williams College, Williamstown, Mass., September 8-11. It is customary for the Society to hold its sessions at some place or institution of special interest to astronomers. In accordance with that practice the Society met to participate in the centenary of the Hopkins Observatory of Williams College. Through kind permission of the Department of Mines and Resources the writer attended these meetings, presented papers prepared by the members of the staff of the Dominion Astrophysical Observatory and visited several observatories en route. Attendance at meetings such as these is found to be of great value to the scientist and, particularly, the astronomer, for whom the tendency to become over-absorbed in his specialty is ever present. He is benefited by the exchange of ideas and information made possible in the scientific sessions and is stimulated by the informal discussions which supplement the scheduled addresses.

There was a large attendance, about 125 members signing the register, and these accompanied by relatives and friends assured a good audience at every session. Papers were presented at four daytime sessions while one evening session was largely devoted to motion pictures and papers concerning the total solar eclipse of June 8, 1937. In addition a popular address was delivered at an afternoon meeting, followed by an inspection of the Hopkins Observatory and astronomical museum and a reception by the President of the College.

There were in all some fifty-three papers upon the programme. This was an extensive list, especially in view of the time available, and consequently discussion after each paper was rather limited, although this was partially compensated for by informal conversation between sessions. Since a detailed list of titles and abstracts will appear in the *Publications of the American Astronomical Society*, it is unnecessary to give a complete summary here, and the writer will content himself with a more general digest of the proceedings.

On Thursday afternoon Professor W. I. Milham, Field Memorial Professor of Astronomy at Williams College, delivered an address entitled "Early American Observatories". In a very interesting and scholarly discourse Professor Milham described the early history of astronomy in the United States, and the construction of telescopes and observatories in the early part of the nineteenth century. The introduction and development of astronomy in Williams College was discussed, leading to the building of the observatory by Professor Albert Hopkins in 1837. The Hopkins Observatory, still being used for instructional purposes, is distinguished as "the oldest living specimen of a permanent observatory in America". After this lecture members of the society were taken on a tour of inspection through the Hopkins Observatory, its astronomical museum and other university buildings. Then followed a reception on the college grounds during which members of the society were able to renew acquaintances and discuss problems in an informal manner.

The scientific programme listed papers dealing with all branches of astronomy. The largest number of papers dealing with one topic concerned the recent total solar eclipse. This was the longest eclipse (7 m. 6.4 s.) "intelligently observed" and as such produced observations of more than usual interest. Eight papers were read giving the results of various observations of eclipse phenomena. At an evening meeting the society was entertained with lantern slides and several reels of motion pictures relating to the eclipse. Some of these were Kodachrome pictures which gave a beautiful and realistic impression of the scarlet flaming prominences and the lambent corona. The registration in these motion pictures was not technically perfect, yet they gave a very good idea of the appearance of the eclipsed sun. In addition to these papers and discussions the society was favoured by an address by Major A. W. Stevens, who is well-known for his high-altitude eclipse photographs and stratosphere flights. His discussion of the possibilities of coronal photography outside eclipse was most instructive and, in the writer's opinion, prophetic.

There were, naturally, many papers upon the various topics embraced by the term "astrophysics". The application of new emulsions, especially those of the red- and infra-red-sensitive types

in studies of star fields, and galactic nebulae, and obscuring material indicates the power and importance of these new photographic materials. Papers upon spectrophotometry and stellar classification were also helpful.

The subject of radial velocities was represented by six papers, three of them dealing with spectroscopic binary orbits. The most important contribution in this field was, "The Radial Velocities of 917 A-type Stars", by Dr. W. E. Harper, an announcement bringing to completion a long programme of such measures. An interesting paper in the field of double-star astronomy was a determination of the visual orbital elements of Alpha Phoenicis by Dr. Alden of Johannesburg. This star, long known as a spectroscopic binary, had its motion detected upon parallax plates.

Several papers dealt with novae, peculiar stars and the more typical variable stars. Of particular interest to students of the solar system were the excellent photographs of Finsler's comet and a spectroscopic study of this object. Methods of technique and the design and application of new instruments were included in the list, and positional astronomy was represented by parallax and proper-motion data.

Nor were the theoretical aspects neglected, contributions being presented in the fields of solar physics, interstellar absorption, statistics of variable stars, and problems of stellar atmospheres.

The interest and value of the trip, for the writer, were enhanced by visits to several observatories and discussions with colleagues upon problems of mutual interest. The David Dunlap Observatory, the Observatory of the University of Michigan and its solar observatory at Lake Angelus (The McMath-Hulbert Observatory) and the Yerkes Observatory of the University of Chicago were visited. Excellent opportunities of inspecting new instruments, of obtaining advice upon matters of technique, and of studying observational materials and results were thus presented in a most profitable fashion. The author cannot refrain from a brief word about the remarkable development in solar research at the McMath-Hulbert Observatory, where a powerful solar tower has been constructed quite recently.* The use of motion-picture film in connection with the solar telescope opens fields for investigation

**Publ. Astron. Obs. Univ. of Mich.*, vol. 7, p. 1, 1937.

and will add greatly to our knowledge of solar phenomena. It was the writer's privilege to spend an entrancing evening viewing the motion pictures of prominences and other atmospheric phenomena in our sun.

Those who attended the nineteen thirty-seven summer meeting of the American Astronomical Society will long remember the hospitable and beautiful New England countryside and Williams College and the profitable and interesting discussions and contacts made while there.

Dominion Astrophysical Observatory,
Victoria, B.C.

THE NEXT SUN-SPOT MAXIMUM*

By Harlan T. Stetson

IF weather depends on sun-spots, then the desirability of predicting coming maxima and minima of solar activity becomes of the greatest public interest. The question of the moment is, when is the next sun-spot maximum due?

If the answer to this question were as simple as adding the 11 years—the *average* length of the solar cycle—to the date of the last maximum, the answer would be as easy as two and two. The next sun-spot maximum would then be due in 1939.

There are good reasons, however, for believing that this is not the best prediction. I have just been examining the records of the last 180 years of sun-spots. In this interval there have been 16 completed cycles since the well-determined minimum of 1755. The average length of time from one sun-spot maximum to the next over this interval is 11.13 years. It is a surprise, and a bit disconcerting, to find only four maxima of the last 16 have fallen within 11 years of each other. Three have been spaced 13 years apart, three 10 years apart, and two at 12-year intervals. Two others were separated by eight years, and there was one instance of 16 years elapsing between two adjacent sun-spot maxima.

On these grounds alone there would be a chance that the next sun-spot maximum might follow anywhere from eight to 16 years after the last maximum, which occurred in July, 1928. There is only one chance in four that the 11-year interval will work for predicting the present coming maximum. . . .

Years have been spent by numerous investigators in analyzing sun-spot curves to discover the various periodicities that may enter into the question. When we examine the sun-spot numbers month by month rather than year by year, it is important to note that there

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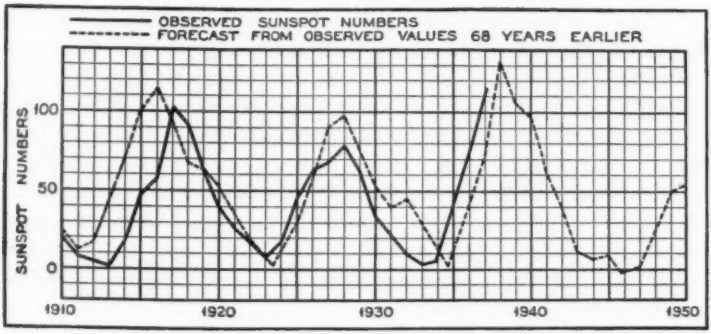
*Part of an article on "Weather and Sun-Spots" in the *Scientific American* for November, 1937. This article is a chapter in a book entitled "Sun-spots and their Effects", recently published by the McGraw-Hill Book Co., N.Y.

are secondary fluctuations that occur at more or less irregular intervals. These secondary or minor fluctuations have an important bearing on the prediction of the maxima. Some of these intervals of variation are much longer than the 11-year cycle, others are shorter.

The most recent and fruitful results which I have yet seen in an attempt to analyze the sun-spot cycle into workable periods which may be used for prediction are those recently shown me by Mr. Clayton. By a rather novel trick he has treated the long record of sun-spot numbers from 1750, and has determined significant periods of 8 1/2 years, 10 years, 11 1/3 years, 14 years, 17 years, 23 years,



34 years, and 68 years. He finds that, from 1750 to 1910, an interval of 68 years gives a close approximation to sun-spot changes. Utilizing the dates of all the well-determined sun-spot maxima and minima published by Wolf and his successor at Zürich, he finds that the mean value using nine intervals based on minima is 68 years, and that the mean value using eight available intervals based on maxima is 67.6 years. Utilizing these intervals of about 68 years, and utilizing only data up until 1910, he has made a forecast of sun-spot numbers from 1910 to 1954. This curve agrees so remarkably with the observed values from 1910 to date that it merits more confidence than any prediction which I have yet seen. [From the curve the maximum should be expected in 1938.]

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THE BRIGHT NOVA OF 1860 IN THE GLOBULAR CLUSTER MESSIER 80, AND ITS RELATION TO SUPERNOVAE

By HELEN B. SAWYER

Introduction

THE numerous discoveries of the past few months of novae having extraordinarily bright absolute magnitudes have awakened interest in this entire class of star. At present in extragalactic nebulae there are twenty supernovae known, many of them with an absolute magnitude of -12 or brighter, as judged by our present knowledge of the distances of these objects. In this connection I have found it interesting to review the history of the nova T Scorpii which appeared in the globular cluster NGC 6093 (Messier 80), R.A. $16^h\ 11^m.1$, Dec. $-22°\ 44'$ (1900) in the year 1860. This is the only nova ever found within the apparent boundaries of a globular cluster. The clusters have been assiduously hunted for variables, and over a thousand variable stars are known in them. But this intense photographic search has not yet yielded a single nova.

References to this nova in the literature of the present day are few and scanty, and I have been able to find no complete account of this remarkable object. Shapley[1] states that it was discovered by Auwers and says "If it is an actual member of the cluster, its absolute magnitude at maximum, when the apparent visual magnitude was 7.0, was -9.2, three magnitudes brighter than the average galactic nova."

This paper falls into three sections. Section A gives an account of the nova of 1860; section B, for comparison, a table of supernovae

[1] *Star Clusters*, 1930, p. 52.

in extragalactic nebulae and a few remarks on them; and section C a bibliography of the nova in Messier 80 and of supernovae.

A. The Nova in Messier 80

On May 27, 1860, Luther[2] announced that Auwers had seen on May 21 in a nebula in Scorpio a bright star which had been invisible on his frequent glances at this nebula since the beginning of the year 1859 and at his last look on the 18th of May 1860. The position of the star was given as R.A. $16^h\ 8^m\ 42^s.42$, Dec. $-22°\ 37'\ 26''.0$ (1860). Luther mentions the fact that Messier and Herschel have observed the nebula and neither of them nor Argelander nor d'Arrest has noticed an especially outstanding star. On the 21st of May Auwers estimated the star as magnitude 7 and Luther as 6.5; on the 22nd of May the magnitude of the star was the same; on the 25th of May it seemed fainter to both Luther and Auwers.

The next reference to the star in the literature is a paper by Pogson,[3] dated Oct. 8, 1860, and titled "Remarkable Changes Observed in the Cluster 80 Messier." The account given by Pogson is considerably more dramatic than that of Luther. I quote from the first two paragraphs.

"This fine globular object, although described as 'a compressed cluster', had, until this year, always presented the appearance of a well-defined nebula to my eye, under the moderate powers with which I have been accustomed to behold it. As it comes in the same field of view with M. Chacornac's pair of variable stars, R and S Scorpii, it has been under regular inspection for the last seven years; from 1853 to 1856 by the French astronomer, and since 1857 by me also. Admiral Smyth examined it in 1837 and again in 1839, but he, as also Messier, Sir John Herschel, Professors Argelander and D'Arrest, recorded it as either 'cometary' or 'nebulous'.

On the 28th of May, when searching after the two above-named variable stars, neither of which was then visible, my attention was arrested by the startling appearance of a star of the 7.6 magnitude in the place which the nebula had previously occupied. The power used was 118, on the Hartwell equatoreal; and so recently as May 9th—the last night on which R Scorpii was visible—I am able to state positively that the nebula was as usual, and had nothing stellar about it, with the self-same power and instrument. On June 10th, with power 66, the stellar appearance had nearly vanished, but the cluster yet shone with unusual brilliancy and a marked central condensation. I mentioned this extraordinary

[2] *A.N.*, v. 53, p. 293, 1860. [3] *M.N.*, v. 21, p. 32, 1860.

phenomenon to Mr. Hind on May 30th, also to Admiral Smyth and Dr. Lee, but pressing and anxious business so distracted my attention about that time that I neglected to announce it *publicly*, and had almost forgotten the occurrence until the arrival of the *Astronomische Nachrichten*, No. 1267, in which Prof. E. Luther of Königsberg corroborated my records. . . .

It is, therefore, incontestably proved, upon the evidence of three witnesses, that, between May 9th and June 10th of this year, the cluster known as 80 Messier changed, *apparently* from a pale cometary looking object, to a well-defined star, fully of the seventh magnitude, and then returned to its usual and original appearance. It seems to me absurd to attribute this phenomenon to actual change in the cluster itself, but it is very singular if a new variable star, the third in the same field of view, should be situated exactly between us and the centre of the cluster. Should such be the true explanation, the mid-way variable star must be similar in nature but of greater range than Mr. Hind's wonderful U Geminorum. The cluster should be closely watched in some Southern Observatory."

In 1862 Auwers[4] published comments on the nova, and its position, which he gave as $0^s.29$ and $2''.7$ distant from the cluster centre in right ascension and declination respectively. It was not until 1886 that he published his actual observations of magnitude.[5] At that time the appearance of the bright star in the Andromeda nebula recalled to importance the earlier nova in Messier 80. Auwers pointed out that in the space of only twenty-five years to have two novae projected against the centre of two objects, M 80 and M 31, was attributing far too much to coincidence, and that it was much more reasonable to assume that these stars were physically connected with the systems in which they appeared. Auwers then proceeded to publish his observations of Nova T Scorpii from the observation journal of variable stars, Königsberg, 1860. Summarized briefly, they are as follows:

1860 May 21, 7.0; May 22, 7.0; May 24, 7.5; May 25, 7.8; June 3, 9.2; June 8, 9.7; June 12, 10; June 16, 10.5.

Figure 1 (p. 72) gives the light curve of this nova as I have been able to construct it from the published observations, mostly those of Auwers. The curve is drawn through the observations of Auwers. On the night when Auwers estimated the star as of mag. 7.0, Luther made it 6.5. It is possible then that all of Auwers' observations are systematically a little faint. This theory is borne out by the fact that Pogson on May 28 estimated the star at magnitude 7.6,

[4] *A.N.*, v. 58, p. 374, 1862. [5] *A.N.*, v. 114, p. 47, 1886.

about a magnitude brighter than the *interpolated* curve of Auwers' observations would lead one to expect. The difficulty of estimating a bright star against the background of a fuzzy cluster is considerable. For the best portrayal of the light curve, then, I have taken entirely Auwers' observations; but for purposes of computing the absolute magnitude of the nova, it is probable that his apparent magnitudes need a correction. Pogson states that there was nothing unusual about the cluster on May 9, and Auwers saw no bright star in it on May 18. I have arbitrarily assumed that they would have noticed a star brighter than the 9th magnitude, and have indicated this in the figure.

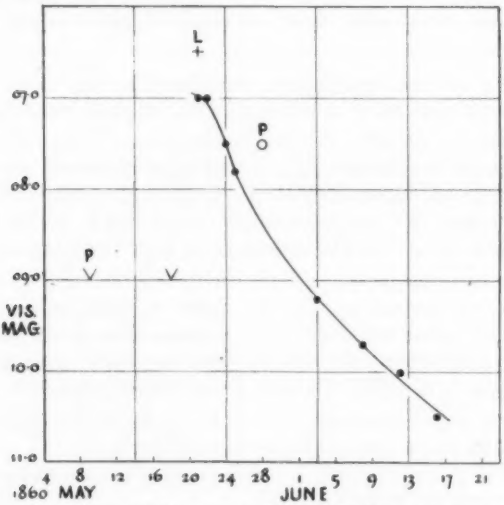

Fig. 1. Light Curve of the Nova in Messier 80 from Auwers' observations. P indicates observations by Pogson; L, Luther's estimate.

Concerning the later history of this nova, the evidence is confusing and contradictory. J. F. G. Schmidt of Athens has a series of reports on the star in the *Astronomische Nachrichten*, concerned with the positions of stars in the region and with the magnitude of the nova. His note[6] in 1861 is concerned with the position of

[6] *A.N.*, v. 54, p. 321, 1861.

the cluster; but in his next note[7] he calls attention to the fact that this is the first known variable star to be associated with a cluster or nebula, and says that it was invisible in the Athens refractor on 1860 July 21, Aug. 20, Sept. 1, Oct. 8; 1861 Jan. 22, 24, 31. His next two notes[8, 9] deal merely with the positions of stars in the regions and the identification of the variables R, S and T Scorpii.

In his next remark he makes[10] the following statement which I translate freely as follows: "T Scorpii, the star in the nebula h3624 (May 1860) has, in numerous observations since 1860, never been seen."

Two years[11] later he repeats the statement as follows: "T Scorpii. The variable near the middle of the star cluster h 3624; since 1860 it has never been visible to me; and in very many observations the nebula also shows no kind of variation."

Seven years[12] later he amplifies his statement still further. "T Scorpii. Since June 1860 T was never visible in this star cluster. h 3624 was very frequently observed, at least 1000 times since 1860."

Schmidt's observations of variable stars go down to the 13th magnitude, which would set a limiting magnitude of probably 12 for a star in a fuzzy object like a cluster.

Meanwhile Schoenfeld published the positions of some variable stars,[13] and a list[14] of variables then known. In 1865 he specifically states that he is not assigning the new variable in M 80 letter T as he considers this not an ordinary variable, but similar to Hind's nova in Ophiuchus. This would seem to mean that he had never heard of the nova's being seen again after its gradual fading from maximum.

But in 1902 Baxendell[15] published some of Pogson's observations which had not been published before his death. And the observations here are in direct contradiction to those made by all other observers. Baxendell says "It is commonly believed that this star has never since been seen. Pogson's observations, however, appear

[7] *A.N.*, v. 55, p. 93, 1861.
[8] *A.N.*, v. 70, p. 250, 1867.
[9] *A.N.*, v. 72, p. 56, 1868.
[10] *A.N.*, v. 72, p. 141, 1868.
[11] *A.N.*, v. 77, p. 123, 1870.
[12] *A.N.*, v. 89, p. 159, 1877.
[13] *A.N.*, v. 70, p. 333, 1868.
[14] *A.N.*, v. 64, p. 169, 1865.
[15] *A.J.*, v. 22, p. 127, 1902.

to prove that either it, or some other star (or stars) in the cluster, exhibit irregular but at times striking, variation.

"On 1863 June 9, what we must at present term T Scorpii appeared = 11.0 magnitude; the following night it was scarcely noticeable. On 1864 January 30 nothing was seen of it, but on February 10 it was = 9.0 magnitude, and on March 5 = 9.3 magnitude. Only two days later, however, it had fallen below 11.5 magnitude. Many other, but probably less striking, variations in the appearance of Messier 80 are recorded by Mr. Pogson."

I possess no knowledge to enable me to decide which of the conflicting reports to accept. But in view of the fact that the discoverer of the nova, Auwers, in 1886 had never observed a brightening of it; that Schmidt at Athens looked at the cluster over a thousand times in the decade after the appearance of the nova and saw no change in it; that Schoenfeld in 1865 certainly did not know of these fluctuations or he would presumably have classed it as a variable rather than as a nova; in view of these facts, and the fact that Mr. Pogson himself never published these later observations of his, the writer is inclined to think that whatever Mr. Pogson saw, it was not the nova T Scorpii.

There are two possibilities; one is that the object Pogson saw was one of the variable stars. These variables have not yet been analysed. Or the nova may actually have had a second outburst which Pogson happened to see, but which was missed by other observers. If there are any unpublished records at any observatory which would settle the question one way or the other, they would be very valuable. This is the first nova to have been seen in any system but our Milky Way clouds and it is certainly desirable to have this ambiguity in its history cleared up.

The cluster Messier 80 has been searched for variables. In 1902 Bailey[16] listed two variables found in this cluster. In 1904[17] Miss Leavitt announced four new variables in the region. In 1924 Bailey[18] published periods for these four and for a fifth. Four are long period variables and one has a period of approximately half a day. None of these variables lies close enough to the cluster, however, to be considered an actual member. They are listed in the regular nomenclature of galactic system variables as TW, UY,

[16] *H.A.*, v. 38, p. 2, 1902. [18] *H.C.O. Bull.*, no. 798, 1924.
[17] *H.C.*, no. 90, 1904 (*A.N.*, v. 167, p. 161).

S, VW, and AR Scorpii. There is apparently no record of an attempt on the part of these observers to determine the periods of the two variables which are probably actually in the cluster, and no further mention is made of the nova.

It now remains for us to consider the probability of the nova being a member of the cluster, in the light of astronomical knowledge which has been acquired since then. At the moment all the arguments seem to be in favour of considering the nova as an actual member of the cluster.

1. The new star was almost exactly in the centre of the cluster. Auwers pointed out at the time of the appearance of the nova in Messier 31, how exceedingly unlikely it was to have a variable in the direct line of sight. The cluster is at galactic latitude -18. While galactic novae do occur at such a high latitude, they are becoming rare at that distance from the galactic plane. If we take the number of galactic novae known in the region $300° - 60°$ long. $\pm$ 20° latitude as 50, and the number of globular clusters in this region as 30, and compute the probability that a nova will fall within 2 minutes of arc of the centre of a cluster, we have then one chance in a thousand of such an happening. . . . To fall within 10 seconds of arc, as Nova T Scorpii did, the chance is diminished to one in one hundred and thirty thousand.

2. Although the argument may not have been specifically advanced in print, for some time it has been felt that T Scorpii, assumed to be at the distance of the cluster, was so much brighter than the average galactic nova that it was logical to consider it as a foreground star, and hence of smaller absolute magnitude. In view of the large numbers of extraordinarily bright novae which have now been found in external systems, this argument certainly no longer holds.

3. The apparent visual magnitude of this nova at maximum was probably about 6.8, taking a mean of Auwers' and Luther's observations. Nothing is known of course concerning the colour index of this particular nova, and as there are conflicting reports of the colour indices of other novae, no correction is made. The brightest stars in this cluster are of photographic magnitude 14.88, and the modulus is taken as 16.22. Since no Cepheid variables are known, the modulus is not determined with a high degree of

accuracy. This gives an absolute magnitude for the nova of about −9.4. Since this is computed from the magnitudes of the bright stars, it is independent of any space absorption which may be present in the region.

Now an inspection of the light curve reveals that the fall in magnitude was exceedingly rapid. From Auwers' observations the magnitude decreased from 7.0 to 9.0 in about 11 days after maximum. According to Zwicky[19] this rate of magnitude decrease is an indication of the absolute magnitude of the nova. Zwicky has shown that the length of time $\tau_{\Delta m}$ which the nova takes to fall Δm magnitudes directly after maximum may be used to determine the absolute magnitude. Taking then Δm as two magnitudes, τ_2 is equal to 11 days, and using Zwicky's curve, we may compute the absolute magnitude of this nova to be about −9.5. This computation is entirely independent of the assumption as to whether the nova is a cluster member; and the absolute magnitude obtained in this way would appear to support the theory that the nova was actually in the cluster.

Curiously enough, a comparison of the fall of magnitude of nova 1860 T Scorpii with the fall of S Andromedae was made as early as 1886 by Dr. R. Copeland. He apparently believed the nova to be actually associated with the cluster, too, and writes as follows[20] in his paper on Nova Andromedae 1885:

"Nevertheless, the fact of the appearance of a similar star in the globular cluster M 80=G.C. 4173=h. 3624 as observed by Prof. Auwers and Mr. Pogson in 1860, goes far towards showing a connection between these sudden outbreaks and their apparent surroundings: . . . . It may be remarked that the decadence of the nova of 1860 was much more rapid than that of the recent star, for Prof. Auwers' figures show that it fell 3 magnitudes in about twenty days, while Nova Andromedae required about eighty days to decrease to the same extent."

In actual luminosity, therefore, Nova T Scorpii does not reach to that attained by the supernovae in nebulae. Since there was an interval of only three days when the star could have attained a

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[19] *P.A.S.P.*, v. 48, p. 191, 1936.
[20] *M.N.*, v. 47, p. 49, 1886.

brighter magnitude, the actual maximum observed must be very close to the true value. On the basis of absolute magnitude, one can hardly class the nova in Messier 80 as a supernova. But a few years ago supernovae were defined by Hubble[21] in a different manner. This object certainly belongs to "that mysterious class of exceptional novae which attain luminosities that are respectable fractions of the total luminosities of the systems in which they appear." Holetschek's[22] visual magnitude for Messier 80 is 7.8 and Nabakov and Vorontsov-Velyaminov[23] have given 7.3 and 7.6 respectively, with a mean of 7.5. At maximum then the nova gave off fully twice as much light as all the rest of the cluster stars put together.

B. Supernovae in Extragalactic Nebulae

In attempting to get an idea of the apparent and absolute magnitudes and the location of the supernovae, I have experienced considerable difficulty in locating the original references. Not only are they scattered widely through the literature, but since the titles of the articles are often vague or misleading, they are not easily located. The terminology of these novae is exceedingly confusing. Part of this is the natural result of the large time interval over which these objects have been found sporadically. These objects are sometimes referred to in variable star nomenclature (S And, T Sco, Z Cen, VW Vir); sometimes in novae terminology (Nova 10.1926 Virginis); and sometimes as the nova in NGC—. To avoid confusion with galactic system novae, the number of the nebula in which the object is located should certainly be given always in the title of a paper.

Table I gives a summary of some of the more important information concerning the supernovae found in extragalactic nebulae. A table of such novae known in 1917 was given by Shapley[24] and another in 1928 by Stratton.[25] But the writer has been able to find no up to date table listing the date of discovery and the date of observed maximum. Both of these dates are essential to a person interested in following the course of knowledge of supernovae; either date without the other is apt to be very confusing.

[21] *Ap. J.*, v. 69, p. 127, 1929.
[22] *Mt. W. Cont.*, v. 161, p. 16, 1918.
[23] *A.N.*, v. 228, p. 425, 1926.
[24] *P.A.S.P.*, v. 29, p. 214, 1917.
[25] *Hand. der Astroph.*, v. VI, pt. 2, p. 256, 1928.

TABLE I

Supernovae in Extragalactic Nebulae

	Date Ann.	N.G.C.	Const.	1950 R.A.	1950 Dec.	Discoverer	Date Obs. Max.	m_{nova}	m_{neb}	M_{nova}
1	1885	224	And	$0^h40^m.0$	+41° 0′	Hartwig*	Aug. 31, 1885	7.0	5±	−14.7
2	1895	5253	Cen	13 37 .1	−31 24	Mrs. Fleming	July 8, 1895	7	10.8	−14
3	1913	3147	UMa	10 12 .8	+73 39	Mrs. I. Roberts	April 6, 1904	13-14	11.9	
4	1917	6946	Cep	20 33 .9	+59 58	Ritchey	July 19, 1917	14.6	11.1	
5	1917	4321	Com	12 20 .4	+16 6	Curtis	Mar. 17, 1901	13.5	10.8	−12.3
6	1917	"	"	"	"	"	Mar. 2, 1914	14	10.8	−12.8
7	1917	4527	Vir	12 31 .6	+ 2 56	"	Mar. 20, 1915	14	11.3	−12.8
8	1917	2841	UMa	9 18 .6	+51 12	Pease	Feb. 19, 1912	16	10.5	
9	1920	2608	Cnc	8 32 .2	+28 38	Wolf	Feb. 7, 1920	10.7	12.9	
10	1922	4486†	Vir	12 28 .3	+12 40	Balanowsky	Feb. 24, 1919	11.5	10.7	>−14.5
11	1923	5236	Cen	13 34 .3	−29 37	Lampland	May 5, 1923	14	10.0	−11
12	1923	2535	Cnc	8 8 .2	+25 21	Reinmuth	Jan. 18, 1901	13.3	<13.0	
13	1925	4424	Vir	12 24 .6	+ 9 42	Wolf	Mar. 17, 1895	10.5	12.6	>−14.3
14	1926	4303	Vir	12 19 .4	+ 4 45	Wolf & Reinmuth	May 9, 1926	14.2	10.4	−12.6
15	1936	4273	Vir	12 17 .4	+ 5 37	Hubble & Moore	Jan. 18, 1936	14	12.2	−12.4
16	1936	4674	Vir	12 43 .4	−56 47	Luyten	May 9, 1907	13.5	14.5	
17	1937	4157	CVn	12 8 .6	+50 46	Zwicky	Feb. 16, 1937	16.2	12.0	
18	1937	I 4182	CVn	13 3 .6	+37 53	"	Aug. 28, 1937	8.5	13	−16.3
19	1937	1003	Per	2 36 .0	+40 40	"	Sept. 10, 1937	12.0	13.7	−14.7
20	1937	I 4719‡	Tel	18 29 .0	−56 46	Miss Boyd	Oct. 11, 1934	13.6	13.9	

*Several other observers saw this nova before Hartwig, but Hartwig publicly announced it first.

†Stratton *op. cit.* lists a 2nd nova found by Wolf in this nebula. I have been unable to find the references to this star.

‡Grateful acknowledgment is given to Miss Boyd who sent the information while the discovery paper was still in press

The supernovae are arranged in this table according to the date when they were announced. This holds also for those announced the same year. Several novae which have been included have been found by only one observer and never verified. It is therefore possible that a re-examination of old plates might lead to one or two of these objects being dropped as defects. It is also possible that some nova has been announced in such an obscure way that the reference is lying neglected in the literature. In general, however, Table I should give a good working list of supernovae in extragalactic nebulae. The novae are numbered in the order of their announcement. The columns of the table give successively the NGC number (IC in two cases) the constellation (determined from the I.A.U. boundaries), and the right ascensions and declinafor 1950. In most cases this has been taken from Shapley and Ames' catalogue.[26] The seventh column contains the name of the discoverer. For only the first supernova in Andromeda is there doubt as to whom to call the actual discoverer. The eighth column gives the date of the brightest observation of the supernova. It will be very rarely that this is the actual date of maximum. Usually there has been a time interval of many days, often of many months, between successive observations on the nebula just before discovery of the nova, so that the nova itself has had plenty of time to pass maximum. The supernovae which are apparently and absolutely brighter than the others, however, probably have been detected much nearer maximum.

The ninth column gives the apparent magnitude of the nova at its greatest observed brightness. For the earlier novae especially, the magnitudes are not mentioned in very precise terms. The tenth column gives the apparent magnitude of the nebula, taken usually from Shapley and Ames' catalogue, sometimes from the paper announcing the discovery of the nova. The last column gives the absolute magnitude of the nova as accepted by astronomers working with nebular distances, or computed from Hubble's accepted modulus[27] 26.8 of the Virgo cluster.

As the list stands, there are twenty supernovae known in extragalactic systems. To get a complete list of such objects one must add Tycho's nova of 1572 in Cassiopeiae. This is accepted

[26] *H.A.*, v. 88, pt. 2, 1932. [27] *P.A.S.P.*, v. 48, p. 227, 1936.

by all observers as a supernova. The status of Kepler's nova of 1604 seems to be still in doubt; Zwicky[28] classes it as a supernova, while Mrs. Payne-Gaposchkin[29] does not. There is also the nova in Messier 80, which, though of absolute magnitude fainter than supernovae, was absolutely brighter than the globular cluster in which it appeared. It seems then, that at least twenty-one supernovae are now known, and possibly one or two more.

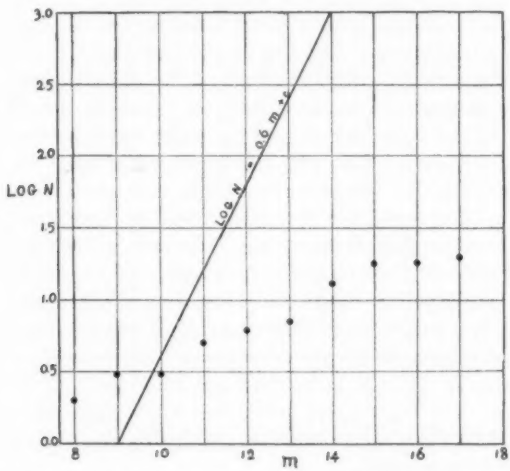

Fig. 2. The number of supernovae brighter than any given apparent magnitude. The straight line gives the number of supernovae to be expected for uniform space distribution (as in extragalactic nebulae) for discovery independent of apparent magnitude.

It is interesting to consider the frequency distribution of apparent maximum magnitudes among these twenty supernovae, and compare it with the numbers of nebulae brighter than successive magnitudes. Figure 2 shows these two quantities compared. The straight line gives the relative number of nebulae, and hence of novae, to be expected on the basis of uniform space distribution. The open circles represent the numbers of supernovae observed down to any given apparent magnitude. Obviously the brightest

[28] *P.A.S.P.*, v. 48, p. 194, 1936. [29] *Telescope*, v. 4, p. 103, 1937.

supernovae will probably be found, and the fainter will usually escape detection. If we assume the discovery of the brightest novae is reasonably complete and judge from the diagram, only about one half of one percent of the novae down to apparent magnitude 15 in external galaxies have been discovered.

The quantity $m_{nova}—m_{nebula}$ is also a rather significant one. From the twenty supernovae known, this quantity has a spread of 11 magnitudes, with a maximum frequency at about +2.5. This can probably be taken as a rough indication of the spread in the absolute magnitudes of the novae themselves, but as there is a spread in absolute magnitude of the nebulae, no very definite conclusions can be drawn.

The ordinary novae seem to have absolute maximum magnitudes from 0 to −9; the supernovae to range from −12 to −16. The filling in of the column of absolute magnitudes of supernovae by astronomers working with the distances of the nebulae in question will be an exceedingly significant one. It may then be found that the apparent break in absolute magnitude in the sequence of novae between −9 and −12 is not a real one. In that case a rigid definition of the term "supernova" is called for. The nova in Messier 80 is apparently either the brightest ordinary nova known, or the faintest supernova.

There are a few comments to make concerning some of the supernovae. The most spectacular of all was the first on the list, S Andromedae, which changed the whole appearance of the great nebula in Andromeda. The remarkable nova of 1860 in Messier 80 had not been in the minds of astronomers, or in the current literature, for some years, and it is not surprising that observers could hardly believe their eyes at the change in appearance of the Andromeda nebula. The Nachrichten[30] states that the Central-bureau received at $10^h\ 38^m$ on the evening of August 31 the following telegram sent from Dorpat at $10^h\ 15^m$: "Höchst merkwürdige Veränderung des grossen Andromedanebels. Fixsternartiger Kern siebenter Grösse. Hartwig."*

Numerous observations, spectrum or direct magnitude esti-

[30] *A.N.*, v. 112, p. 245, 1885.

*Most remarkable variation of the great nebula in Andromeda. Starlike nucleus of the seventh magnitude.

mates, were made on this remarkable star. Ten years later the next supernova appeared, found by Mrs. Fleming[31] by its peculiar spectrum, and known in the literature as Z Centauri. The status of the nebula in which this nova appeared is still in doubt, as the nebula has a bright-line spectrum. Hubble and Humason[32] have raised the point as to whether the nebula is a planetary or not. Zwicky[33] and Mrs. Payne-Gaposchkin[34] appear to accept NGC 5253 as an extragalactic nebula and Z Centauri as a supernova. Mrs. Payne-Gaposchkin from a study of the spectra of Z Centauri deduced a velocity of expansion of the nova of the order of 10,000 km/sec, a result the order of which was later confirmed at Mount Wilson from up to date observational material on recent supernovae.

For nearly twenty years no further discoveries of very bright novae associated with nebulae were made. In 1913 Mrs. Roberts[35] found evidence of such a star in NGC 3147 and asked for confirmatory evidence. Later Mrs. Roberts[36] announced another possible new star in the nebula NGC 7331, but the following year Lundmark[37] showed this to be a defect. But in 1917 the whole subject of bright novae associated with extragalactic nebulae was very much in the literature. It is a bit surprising to find that nearly as many were found in that year as in the years 1936-37 when supernovae have been receiving so much prominence. There is this difference between the supernovae found in 1917 and those of the last two years. Of the five 1917 novae, only one was found when it was anywhere near maximum. Of the six novae 1936-37, four were found while near maximum. It was Ritchey's[38] discovery of the nova in NGC 6946 near maximum which gave the impetus to the search of existing nebular photographs for other such objects. Curtis[39] was rewarded by finding three extraordinarily bright novae, two of which were in one nebula, NGC 4321. Pease[40] also found a bright nova. Ritchey[38] lists as well some suspected objects in other nebulae, M 81, M 101 and NGC 2403, but Hubble[41]

[31] *A.N.*, v. 139, p. 249, 1896.
[32] *Com. Nat. Acad. Sc.*, no. 116, p. 2, 1934.
[33] *P.A.S.P.*, v. 48, p. 194, 1936.
[34] *Ap. J.*, v. 83, p. 173, 1936.
[35] *A.N.*, v. 197, p. 57, 1913.
[36] *C.R.*, v. 173, pp. 1072-4, 1921.
[37] *P.A.S.P.*, v. 34, p. 53, 1922.
[38] *H.C.O. Bull.*, no. 641, 1917.
[39] *L.O.B.*, no. 300, 1917.
[40] *P.A.S.P.*, v. 29, p. 213, 1917.
[41] *Ap. J.*, v. 69, p. 127, 1929.

shows that none of these is a nova. Some are variables and one is apparently a defect on the plate.

Between 1926 and 1936 there appears to be a gap when no supernovae were announced. A great many ordinary novae had of course been found in the Andromeda nebula.[41] In the years 1936 and 1937 six supernovae have been announced.

The first nova found as a result of a systematic programme of photographing the brighter groups of nebulae was announced by Hubble and Moore[42] in 1936 in the nebula NGC 4273. A systematic search of extragalactic nebulae for bright novae was first suggested by Curtis,[39] who remarked that a programme of photographing the spirals every two years with short exposures would lead to the detection of these bright objects. It was the discovery[43] of the nova in the Virgo cluster in 1926 (NGC 4303) which prompted the search at Mount Wilson, carried on since 1928 with the 10-inch Cooke refractor, first by Hubble and later by Baade. The nova in NGC 4273 was announced near maximum and was bright enough so that an excellent light curve and several good spectrum observations were obtained. Humason[44] gives an account of the early spectrum, when the velocity of expansion was around 2200 km/sec, and Baade[45] describes the later spectrum, at magnitude 17.4, which consisted of a single wide band of N III with a velocity of 6600 km/sec. Although Curtis first suggested the systematic search, it remained for Baade and Zwicky[46] to point out that supernovae exist as a definite class of object, and to indicate some of the many important ways in which they can be expected to contribute to astronomical knowledge.

A similar supernova search by Zwicky[47] yielded three supernovae in the year 1937. Zwicky's programme has been carried out with the 18-inch Schmidt telescope at Mt. Palomar. In nine months, beginning in September, 1936, he took 300 photographs of the Virgo cluster and other nearby nebulae. Between 5,000 and 10,000 nebular images were searched for new stars. The first result was the announcement of the supernova in NGC 4157 in February 1937. Zwicky estimated it to be at maximum in January of that year;

[42] *P.A.S.P.*, 48, pp. 108-110, 1936.
[43] *Harv. Ann. Card* 3, 1926.
[44] *P.A.S.P.*, v. 48, pp. 110-3, 1936.
[45] *P.A.S.P.*, v. 48, p. 226, 1936.
[46] *P.N.A.S.*, v. 20, p. 254, p. 259, 1934.
[47] *P.A.S.P.*, v. 49, pp. 204-6, 1937.

while his observed maximum magnitude is 16.2, by a comparison of its light curve with that of nova 1936 in NGC 4273 he considers the maximum magnitude to have been 14.6.

The second supernova announced by Zwicky[48] in August, 1937, is one of the most important ever found, for it reached the amazingly bright apparent magnitude 8.5. Only the supernovae in Messier 31 and NGC 5253 have exceeded it in apparent magnitude. The spectrum observations of this object should be exceedingly numerous, and of great observational value. Already the German astronomers Walter[49] and Strohmeier have published accounts of the spectrum, which resembled that of a Wolf-Rayet star with very broad bands.

The last supernova to be announced was found by Miss Boyd[50] during a search for variables on Harvard plates. As even small scale plates are of value in a search for these striking objects, one would expect that the wealth of plates accumulated at the Harvard Observatory would be a rich field to search for these stars.

Six supernovae have had photographic observations of the spectrum; those in NGC 1003, 4273, 4303, 5253, 6946, and IC 4182. A seventh, Nova Andromeda 1885 in M 31, had numerous visual spectrum observations which have recently been written up in detail by Mrs. Payne-Gaposchkin.[51] She has also summarized the spectrum observations of Z Centauri,[52] and dispelled the earlier theory that it had an R type spectrum by showing that the spectrum probably consisted of a broad band with a velocity of the order of 10,000 km/sec.

C. Bibliography

To save time for workers in this subject, a bibliography has been prepared in three parts. The first part gives references to all the material on the nova in Messier 80. These references have been included in footnotes in part A of this paper, but they are here gathered together chronologically for convenience.

The second section gives the bibliography of bright novae in individual nebulae. The nebulae are arranged according to right

[48] *Harv. Ann. Card* 427, 1937.
[49] *A.N.*, v. 263, p. 399, 1937.
[50] *H.C.O. Bull.*, no. 907, 1937.
[51] *Ap. J.*, v. 83, pp. 245-51, 1936.
[52] *Ap. J.*, v. 83, pp. 173-6, 1936.

ascension; all but two have NGC numbers. For the two earliest supernovae S Andromedae and Z Centauri, the bibliography is not complete, giving only a few key papers. A complete bibliography of S Andromedae is practically a whole paper in itself. There are 49 separate references to this star in volume 112 of the Astronomische Nachrichten alone. For all the other supernovae the bibliography aims at completeness. For many references a few words of summary have been included as a guide to the nature of the article.

The third part lists a few papers of a general nature dealing with supernovae.

Bibliography of Nova in Messier 80

1860 Luther, E., Aus einem Schreiben des Herrn Prof. Luther, Directors der Sternwarte in Königsberg, an den Herausgeber. *A.N.*, v. 53, p. 293.

1860 Pogson, N., Remarkable changes observed in the Cluster 80 Messier. *M.N.*, v. 21, p. 32.

1861 Schmidt, J. F. J., Beobachtungen auf der Sternwarte zu Athen im Jahre 1860. *A.N.*, v. 54, p. 321.

1861 Schmidt, J. F. J., Über einen neuen veränderlichen Nebelstern. *A.N.*, v. 55, p. 93.

1862 Auwers, A., Verzeichniss Öder rter von vierzig Nebelflecken, aus Beobachtungen am Königsberger Heliometer abgeleitet. *A.N.*, v. 58, p. 374.

1865 Schönfeld, E., Mittlere Oerter für 1855.0 von veränderlichen Sternen mit Einschluss derjenigen neuen Sterne, deren Positionen sich mit einiger Sicherheit. *A.N.*, v. 64, p. 169.

1867 Schmidt, J. F. J., Bemerkungen über Nebel und Veränderliche Sterne. *A.N.* v. 70, p. 250.

1868 Schönfeld, E., Notiz über die Oerter der Veränderlichen R, S, T Scorpii. *A.N.*, v. 70, p. 333.

1868 Schmidt, J. F. J., Ueber Veränderliche Sterne R, S, T Scorpii. *A.N.*, v. 72, p. 56.

1868 Schmidt, J. F. J., Bemerkungen über einige veränderliche Sterne. *A.N.*, v. 72, p. 141.

1870 Schmidt, J. F. J., Beobachtungen von veränderlichen Sternen auf der Sternwarte zu Athen im Jahre 1870. *A.N.*, v. 77, p. 123.

1862-1875 Schönfeld, E., Astronomische Beobachtungen auf der Grossherzoglichen Sternwarte zu Mannheim, v. I & II.

1877 Schmidt, J. F. J., Veränderliche Sterne, 1876. *A.N.* v. 89, p. 159.

1886 Auwers, A., Aus einem Schreiben des Herrn Geheimrath Auwers, und Beobachtungen der Nova Scorpii von 1860. *A.N.*, v. 114, p. 47.

1902 Baxendell, J., Notes on Pogson's Observations of U Geminorum, T Scorpii, etc. *A.J.*, v. 22, p. 127.

1930 Shapley, H. The Nova in Messier 80. *Star Clusters*, p. 52.

BIBLIOGRAPHY OF SUPERNOVAE

NGC 224 = M 31

1885 Hartwig, E., Ueber eine Veränderung des grosses Andromedanebels. *A.N.*, v. 112, p. 245. Telegram of discovery.

1885 Maunder, A. S., The new star in the great nebula in Andromeda. *Observatory*, v. 8, pp. 321-325. Current summary.

1886 Hartwig, E., Ueber den neuen Stern im grossen Andromedanebel. *A.N.*, v. 113, p. 21. Light curve.

1886 Copeland, R., On Hartwig's nova Andromedae. *M.N.*, 47, p. 49. Lengthy discussion.

1936 Gaposchkin, C. P., On the spectrum of the supernova S Andromedae. *Ap. J.*, v. 83, pp. 245-51. Summary of all spectrum observations.

For the early observations of this star, see Astronomische Nachrichten, vols. 112, 113, 114; *Monthly Notices*, 46, 47, 48; *Observatory*, vols. 8, and 9, etc.

NGC 1003

1937 Supernova in NGC 1003. *Harv. Ann. Card*, 429. Discovery by Zwicky.

1937 Supernova in NGC 1003. *Harv. Ann. Card*, 430. Max. mag. 12.

1937 Another new supernova. *Science Supp.*, no. 2230 p. 8. Distance 7 million light years.

1937 Strohmeier, W., Neue Supernova Zwicky 145.1937 Persei in NGC 1003. *A.N.*, v. 263, p. 448. Observations by Strohmeier, Wachmann and Morgenroth.

1937 Morgenroth, O., Supernova 145.1937 Persei. *A.N.*, v. 264, p. 115. Four observations.

1937 Supernovae. *Gazette astronomique*, v. 24, pp. 82-3. Information about Zwicky's nova.

1937 Drei weitere Supernovae. *Die Himmelswelt*, v. 47, p. 228. Summary of Zwicky's nova.

NGC 2535

1923 Reinmuth, K., Nova 100.1901 Cancri in NGC 2535. *A.N.*, v. 221, p. 47. Discovery.

NGC 2608

1920 Wolf, M., Nova oder Variabilis 3.1920 Cancri. *A.N.*, v. 210, pp. 373-6 = BZ, v. 2, p. 22, no. 14. Discovery.

1920 Miethe, A., Nova Cancri 3.1920. *A.N.*, v. 211, p. 31. Observation.

1920 Reinmuth, K., Photographische Örter der Kerne und der Nova im Spiralnebel NGC 2608. *A.N.*, v. 211, p. 191. Positions of nucleus and nova.

1920 Graff, K., Nova Cancri 1920. BZ, v. 2, p. 47, no. 30.
1920 Baade, W., Nova Cancri 1920. BZ, v. 2, p. 67, no. 43.

NGC 2841

1917 Pease, F. G., A suspected nova in NGC 2841. *P.A.S.P.*, v. 29, p. 213. Discovery, found independently by Curtis.

NGC 3147

1913 Roberts, Mrs. Isaac, The region of HI 79 Ursae Majoris. An appeal. *A.N.*, v. 197, p. 57. Discovery.

NGC 4157

1937 Zwicky, F., A supernova in NGC 4157. *P.A.S.P.*, v. 49, pp. 204-6. The discovery is the first result of the systematic search for supernovae.
1937 Drei weitere Supernovae. *Die Himmelswelt*, v. 47, p. 228. Information on Zwicky's nova.

NGC 4273

1936 Hubble and Moore, A supernova in the Virgo cluster. *P.A.S.P.*, v. 48, pp. 108-10. Discovery.
1936 Humason, M. L., The spectrum of a supernova in NGC 4273. *P.A.S.P.*, v. 48, pp. 110-3. Velocity 2200 km/sec.
1936 Baade, W., Further notes on the supernovae in NGC 4273. *P.A.S.P.*, v. 48, p. 226. Light curve; velocity later became 6600 km/sec.
1936 Supernova discovered by Hubble and Moore. *Science Supp.*, no. 2157, p. 13.
1936 Le supernovae. *Coelum*, v. 6, pp. 177-80. Summary of notes in *P.A.S.P.*, v. 48.
1936 Eine Supernova und ihr Spektrum. *Die Himmelswelt*, v. 46, pp. 151-2. Summary.

NGC 4303 = M 61

1926 Discovery by Wolf and Reinmuth. *Harv. Ann. Card*, 3.
1926 Nova in NGC 4303. *H.C.O. Bull.*, no. 836. Observations.
1926 Faint nova in nebula. *Pop. Ast.*, v. 34, p. 402. Discovery.
1926 Wolf, M., Nova 10.1926 Virginis. BZ, v. 8, no. 20.
1926 Wolf, M., BZ, v. 8, no. 21.
1926 Steavenson, W. H., Nova Virginis in NGC 4303. *M.N.*, v. 87, pp. 568-73. Three observations.
1926 Steavenson, W. H., Two recent novae. *J.B.A.A.*, v. 36, p. 242. Visual magnitude faded more than photographic.
1926 Shane, C., Spectrum of nova in NGC 4303. *P.A.S.P.*, v. 38, p. 182. Continuous spectrum, might be bright bands in ultraviolet.
1926 Dyson, F., Note on the nova in NGC 4303 (M 61). *M.N.*, v. 86, p. 636. Observations.

NGC 4321 = M 100

1917 Curtis, H. D., New stars in spiral nebulae. *P.A.S.P.*, v. 29, pp. 180-2. Has found three new novae, two in NGC 4321, one in NGC 4527.

1917 Novae in NGC 4321. *H.C.O. Bull.*, no. 642. Announces Curtis' discovery.

1917 Curtis, H. D., Three novae in spiral nebulae. *L.O.B.*, no. 300, pp. 108-10. Also *Nature*, v. 100, p. 174. Magnitudes and positions of these and of one in NGC 4527.

NGC 4424

1925 Wolf, M., Variabilis (? Nova) 94.1925 Virginis. *A.N.*, v. 226, pp. 75-78. Discovery and observations of this nova of 1895, which is also called VW Virginis.

NGC 4486 = M 87

1922 Balanowsky, I., Ein merkwürdiger Veränderlicher oder neuen Stern 1.1922 Virginis. *A.N.*, v. 215, p. 215. Discovery and observations.

1923 Hubble, E., Messier 87 and Belanowsky's nova. *P.A.S.P.*, v. 35, p. 261. Two observations from 100″ plates.

1924 Nova in Messier 87 (Balanowsky 1919). *H.C.O. Bull.*, no. 803. One observation by Miss Woods on Harvard plates.

NGC 4527

1917 Curtis, H. D., New stars in spiral nebulae. *P.A.S.P.*, v. 29, pp. 180-2. Discovery announced with the two in NGC 4321.

1917 Curtis, H. D., Three novae in spiral nebulae. *L.O.B.*, no. 300, pp. 108-10, also *Nature*, v. 100, p. 174. Positions and magnitudes of this nova, and those in NGC 4321.

NGC 4674

1936 Supernova in NGC 4674. *Harv. Ann. Card*, 399. Luyten reports discovery, at max. in 1907. Found on two plates.

IC 4182

1937 Supernova in IC 4182. *Harv. Ann. Card*, 427. Aug. 30. Zwicky announces discovery, mag. 8.5 on Aug. 28.

1937 Discovery of a supernova in Canes Venatici. *Nature*, v. 140, p. 500. Announcement of discovery and of Humason's spectrum observation.

1937 Stobbe, J., Auffindung einer Supernova 144.1937 Can. Ven. *A.N.*, v. 263, p. 379. Observation and position.

1937 Walter and Strohmeier, Über das Spektrum der Supernova 144.1937. *A.N.*, v. 263, p. 399. Broad emission lines on a continuous background.

1937 Nova 144.1937 Canum Venaticorum in IC 4182. *A.N.*, v. 263, p. 445. Observations by Leutenegger, Henz, Morgenroth and Lacchini.

1937 Morgenroth, O., Supernova 144.1937 Canum Ven. *A.N.*, v. 264, p. 115. Seven observations.

1937 Strohmeier, W., Das Spektrum der Supernova 144.1937 C Vn vom 31 August bis 7 Sept. 1937. *Zeit. f. Ast.*, v. 14, pp. 227-8. Broad emission band at λ4680.

1937 Supernovae. *Gazette astronomique*, v. 24, pp. 82-3. Summary of Zwicky's nova.

1937 Drei weitere Supernovae. *Die Himmelswelt*, v. 47, p. 228. Information on Zwicky's nova.

NGC 5236 = M 83

1923 Nova in Messier 83. *H.C.O. Bull.*, no. 786. Discovery by Lampland.

1923 Lampland, C. O., The new star in the great spiral nebula NGC 5236 = M 83. *P.A.S.P.*, v. 35, p. 166. Outburst occurred between May 29, 1922 and May 5, 1923.

1923 Lampland, C. O., Nova in NGC 5236. *Pop. Ast.*, v. 31, p. 648. Maximum light apparently missed.

1936 Lampland, C. O. *P.A.S.P.*, v. 48, pp. 320-21. Calls attention to his 1923 nova which has escaped attention.

1937 Una supernova del 1923. *Coelum*, v. 7, p. 31. Abs. mag. Lampland's nova −11 from Hubble's distance of 3 million light years.

NGC 5253

1895 Pickering, E. C., A new star in Centaurus. *A.N.*, v. 139, p. 249. Found by Mrs. Fleming from peculiar spectrum.

1924 Walker, A. D., Photographic light curves of 13 novae. *H.C.O. Ann.*, v. 84, pp. 189-206. Curve from 1889-1919.

1936 Gaposchkin, C. P., Note on the spectrum of Z Centauri. *Ap. J.*, v. 83, pp. 173-176. Broad bright lines, velocity of order of 10,000 km/sec. Gives references to spectrum observations.

IC 4719

1937 Boyd, C., Supernova in IC 4719. *H.C.O. Bull.*, no. 907. Discovery and observations from all existing Harvard plates.

NGC 6946

1917 Discovery by Ritchey, and spectrum observation. *H.C.O. Bull.*, no. 641.

1917 Wolf, M., Nova Ritchey. *A.N.*, v. 205, p. 79. Position and magnitude.

1917 Wolf, M., Aufsuchungskärtchen für die Nova Ritchey. *A.N.*, v. 205, p. 95. Photograph of nebula and nova.

1917 Nova Ritchey. *Observatory*, v. 40, pp. 455-6. Reproduction of Wolf's photograph and summary of his article. Spectrogram by Ritchey and Pease shows continuous spectrum with bright bands.

1918 Wolf, M., Vom neuen Stern in NGC 6946. *Sirius*, v. 51, pp. 2-3. Two plates of nebula with and without the nova.

GENERAL REFERENCES ON SUPERNOVAE

Baade, W. and Zwicky, F., On supernovae. *P.N.A.S.*, v. 20, p. 254 = Mt. W. Comm., no. 114, 1934.
————————Cosmic rays from supernovae. *P.N.A.S.*, v. 20, p. 259 = Mt. W. Comm., no. 115, 1934.
————————Remarks on supernovae and cosmic rays. *Phys. Rev.*, v. 46, p. 76, 1934.
Curtis, H. D., Novae in spiral nebulae and the island universe theory. *P.A.S.P.*, v. 29, pp. 206-7, 1917.
Gaposchkin, C. P., On the physical condition of the supernovae. *P.N.A.S.*, v. 22, pp. 332-5, 1936.
————————New stars. *The Telescope*, v. 4, pp. 100-106, 1937.
Grotrian, W., Über Supernovae. *Naturwissenschaften*, v. 22, pp. 665-7, 1934.
Hogg, F. S., Recent supernovae in extra-galactic systems. *R.A.S.C. Journal*, v. 31, pp. 351-2, 1937.
Hubble, E., The great spiral in Andromeda. *Ap. J.*, v. 69, p. 127, 1929.
————————The Realm of the Nebulae, 1936, pp. 85-89.
La Meillaie, E. de, Les supernovae. *L'Astronomie*, Jan. 1936, pp. 41-2.
Lundmark, K., The absolute magnitudes of novae. *P.A.S.P.*, v. 34, p 207, 1922.
Observatory, The magnitudes of novae in spiral nebulae. *Obs.*, v. 41, pp. 103-4, 1917.
Ritchey, G., Novae in spiral nebulae. *P.A.S.P.*, v. 29, pp. 210-2, 1917.
Russell, H. N., Novae and supernovae. *Sci. Am.*, v. 155, pp. 146-7, 1936.
Shapley, H., Note on the magnitudes of novae in spiral nebulae. *P.A.S.P.*, v. 29, p. 214, 1917.
Stratton, F. J. M., Novae. *Hand. der Astrophysik*, v. VI, pt. 2, p. 256, 1928.
Zanstra, H., Evidenz für Supernovae als Erzeuger kosmischer Strahlung. *Naturwissenschaften*, v. 23, pp. 867-8, 1935.
Zwicky, F., Stellar guests. *Sci. Mon.*, v. 40, p. 461, 1935.
————————Life luminosity relation for novae. *P.A.S.P.*, v. 48, pp. 191-4, 1936.
————————An expansion luminosity relation for novae. *P.N.A.S.*, v. 22, pp. 457-62, 1936.
————————Characteristic temperatures in supernovae. *P.N.A.S.*, v. 22, pp. 557-61, 1936.

Richmond Hill, Ontario,
January 24, 1938.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Four Interesting Meteors Observed in Italy

M. Eppe Loreta of Bologna, Italy, makes regular visual observations of all the major meteor showers. As a result of his years of experience in recording meteors he has acquired great facility in this work and has frequently been able to note accurately a surprising amount of detail concerning some of the brighter and more unusual meteors. Below are given the details of four interesting meteors which M. Loreta has reported to the writer during the past few months. Except in the case of the third meteor, that of Aug. 9, all observations are by Loreta himself, made in Bologna.

Nebulous Meteor:—May 13, 1937 at 21^h 24^m G.C.T. This meteor, of about the 3rd magnitude, had a short path three degrees in length extending from R.A. 15^h 55^m, Dec. +1°, to R.A. 16^h 07^m, Dec. −1°. It was slow, duration 2 sec., and appeared nebulous with a diameter of 10 minutes of arc.

Fireball:—Aug. 4, 1937 at 0^h 13^m G.C.T. This meteor was a Perseid of magnitude zero which, as it brightened, disappeared behind a house on the south horizon. A persistent train was left at the point where it disappeared. This remained visible in binoculars (aperture 1.8 in.) for 25 seconds and moved 10 minutes of arc to the south-west during this time. No second observation of this train was made but, assuming it to be at an altitude of 90 km., a rough average for night trains, the observed altitude of 12 degrees would place it at a distance of 380 km. from Bologna. In this case the minimum possible velocity of drift (found by assuming a motion at right angles to the line of sight), comes out as 160 km/hr to the SW. The estimate of 10 minutes of arc for the drift was probably made with reference to the terrestrial horizon but if it referred to the stars then the above velocity should be even higher. Though only of zero magnitude as observed in Bologna this fireball would have appeared of magnitude −4 or −5 if seen in the zenith.

Fireball:—Aug. 9, 1937 at 22^h 02^m G.C.T. This meteor was not observed in Bologna but was recorded by two members of a

group of Italian meteor observers organized by Loreta. At Florence the fireball was seen by P. Tempesti at the Observatory of Arcetri. It was estimated as of magnitude −2 and was slow and white, leaving a persistent train visible to the naked eye for 25 sec. The second observation was made at Livorno by Mme. C. Corucci, giving a base line for the two observations of just under 80 km. At Livorno the meteor appeared to be of magnitude −2.5, was fast and left a persistent train visible for 20 sec. The apparent path in the sky was well determined at each station and a graphical solution for height by the writer yields the following results:—

Height of appearance	150 km
" " train	92
" " disappearance	64
Length of path	100

Radiant near R.A. $22^h\ 20^m$, Dec. +67°, at an altitude of 60°.

The above altitudes were determined by a graphical adaptation of the Newton-Denning method. The train height is the best determined while the height of appearance is the least definite. The observer at Florence was looking in another direction when the meteor appeared and did not see the first part of the path. Allowance was made for this in the computations but it is possible that the height of appearance as given above is still too low.

The more one deals with meteor heights the more one realizes the indefinite nature of the so-called points of appearance and disappearance. An average meteor increases and decreases in luminosity so gradually that relatively slight changes in the distance of the observer from the meteor, as well as differences in acuteness of vision, the coefficient of attention, and atmospheric absorption, will considerably alter the apparent positions of appearance and disappearance of any particular object. Then again, telescopic observations will generally reveal a much longer path than that observed visually, while the photographed path will be considerably shorter than the visual. It seems a pity that, in the past, such emphasis has been laid on the exact position of these rather ephemeral points instead of on the height of true maximum luminosity of the meteor or the heights of positions of approximately equal luminosity on either side of the maximum. The latter data are more susceptible of accurate treatment when dealing with the physical theory of meteors and the upper atmosphere.

Detonating Fireball:—Nov. 13, 1937 at $3^h\ 54^m$ G.C.T. Though

this very bright object appeared near the time of the Leonid maximum it was apparently not connected in any way with that shower. Loreta describes it as being at first of magnitude 0 and then steadily increasing in luminosity to magnitude −10. Its duration was 3 seconds and it threw off sparks. A persistent train remained visible for 30 sec. to the naked eye but was followed for 10 minutes in binoculars of 1.8 in. aperture. During this time some interesting changes in position and form took place as illustrated in figure 1. Irregular deformations of the train were evident within a minute of the fireball's appearance. Loreta noted the fact that,

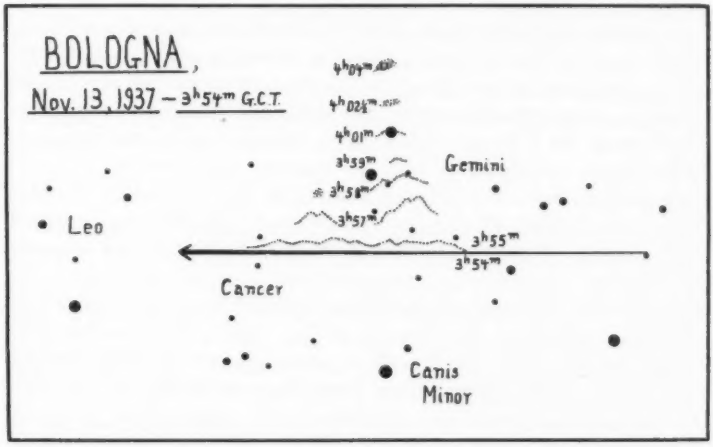

Fig. 1. Detonating fireball and train observed in Bologna by M. Eppe Loreta.

after the train had divided into two segments at 3.57, the left portion was decidedly the brighter but disappeared six minutes before the other part of the train. This behaviour is rather anomalous as generally the brightest portions of a train remain visible longest.

Loreta circulated a request for observations of this meteor but received only general reports which gave no position for the path and thus the height cannot be computed. An observer in Cireglio, F. Ferretti, about 72 km. SSW of Bologna, heard a loud detonation after the meteor appeared but further definite information is lacking.

If we assume, as before, that the mean position of the train was at a height of 90 km., then the observed drift over the ten minute interval corresponds to a minimum possible velocity of 210 km/hr toward the north.

PERSEID OBSERVATIONS MADE ON MT. FUJI, JAPAN

Dr. M. Huruhata, whose work on meteors has several times been reported in these columns, made an expedition to the summit of Mt. Fuji in the summer of 1937 for the purpose of observing the Perseid meteors. Fuji is the highest mountain in Japan, having an altitude of 12,400 ft. above sea level. Its bare, treeless summit provides an excellent site for observation of the sky.

During the night of Aug. 10-11 Dr. Huruhata made observations at the base of the mountain. On the following night, Aug. 11-12, both photographic and visual observations were carried out on the summit, perfect weather conditions being encountered. Exposures were made for 7 hours with a direct camera and a spectrograph. Two direct photographs but no spectra were secured. Visual observations were carried out from 1.44 a.m. to 3.14 a.m. and during this period 47 Perseids and 18 Non-Perseids were recorded and plotted. Though Dr. Huruhata has often observed meteors in Nagano prefecture, where excellent weather conditions are encountered, he expresses himself as astonished at the remarkably clear sky seen from the summit of Mt. Fuji. Mr. Tanaka, who when observing with Dr. Huruhata records about the same number of meteors, made observations from Nagano prefecture on Aug. 11-12. Although weather conditions were perfect here also the hourly rates in Nagano were only about half those determined on Mt. Fuji. For comparison with the Ontario observations Huruhata's rates may be reduced to six observers plotting, giving 110 meteors per hour for Perseids and 42 per hour for Non-Perseids. The Japanese observations were undoubtedly made at least a full day before the Perseid maximum. In Ontario, over half a day later (see the JOURNAL for Dec. 1937), the rates were still only half those observed on Mt. Fuji, being between 50 and 60 per hour for Perseids and about 20 per hour for Non-Perseids. These values check with the rates found by Tanaka in Nagano so the conclusion seems fairly definite that the high altitude of Mt. Fuji doubled the number of meteors seen.

P. M. M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Canadian Astronomers Honoured

Among the officers of the American Association for the Advancement of Science for 1938 are two Canadian astronomers. In the Association considered as a whole Mr. R. Meldrum Stewart, Dominion Astronomer, Ottawa, is Chairman of Section D (Astronomy). The summer meeting of the Association will be held in Ottawa, June 27 to July 2.

The Association became so large and its members so widespread that some years ago a Pacific Division was formed by "fission" from the main body, the two comprising the same "system". This Division will hold its annual meeting at San Diego, Cal., June 20 to 25, under the presidency of Dr. John S. Plaskett, of Victoria, B.C. An attendance of between 700 and 800 members is expected.

A Famous Relativity Limerick

The limerick referred to was printed in this Journal, vol. 20, p. 304, 1926. It was repeated to the present writer by an American astronomer who said it was attributed to the Bishop of Chelmsford. The real author was A. H. R. Buller, who was professor of botany in the University of Manitoba 1904-1936, and was president of the Royal Society of Canada in the year 1927-28. He was awarded the Flavelle medal of that society in 1929 and the Royal medal of the Royal Society (of London) in 1937. The whole story is given in a letter to *The Observer* (London) which is quoted below.

A Famous Limerick

As the author of the relativity limerick, perhaps I may be allowed to say that the limerick was made by me about fifteen years ago while sitting in the garden of my friend and former colleague, Dr. G. A. Shakespear, Lecturer on Physics at the University of Birmingham.

After conversing together on Einstein's theory, I suggested that we should each try to make a relativity limerick. At the end of about five minutes the limericks were ready and were exchanged, but with nothing more than a trace of mutual admiration.

Some two years later, in 1923, at a meeting of the Scientific Club of Winnipeg, a paper on relativity was presented by a physicist and an engineer asked why it had been assumed that the greatest speed was that of light. I then said that, for my purpose, I had assumed that there was a speed greater than that of light, and that I had introduced this idea into a limerick, which, with the chairman's permission, I would recite. The verse was received with laughter and applause.

Three days later I was walking along Portage Avenue, Winnipeg, on my way to the University of Manitoba, when I met a reporter from the *Winnipeg Free Press*. "Buller," he said, "I have heard that limerick of yours. It is very good. I sometimes send things to *Punch* and, if you don't mind, I should like to send that."

"Thank you very much," I replied, "but, if my limerick is going to *Punch*, I would rather send it myself." On arriving at the university I wrote out the limerick and at once sent it off to *Punch*. Six weeks later I received from the editor a copy of *Punch* with my limerick in it, and an honorarium of a few shillings.

The original form of the limerick was as follows:—

There was a young lady named Bright,
Whose speed was far faster than light;
She set out one day,
In a relative way,
And returned home the previous night.

Since the relativity limerick was published I have noted that at various times it has been attributed to three bishops and to a well-known American authoress.—*A. H. Reginald Buller.*

An Atomic-Physics Observatory

The Carnegie Institution of Washington was founded on January 28, 1902, with Terrestrial Magnetism as one of its Departments. Under the able and active direction of L. A. Bauer great additions were made to our knowledge of the magnetic elements on the lands and oceans of the world. But while the field of research of this Department is the earth as a magnet this is intimately related to the atmosphere. Consequently the Department has made basic studies of magnetism and has also explored the earth's high atmosphere by means of radio waves. No better illustration can be found of the fundamental unity of the physical sciences.

In the latest Annual Report of the Director, among many other things, we find discussions of artificial neutron-sources, the transmutations of lithium, and the atomic-physics observatory. Regarding the latter we may quote the following:

A major development, which will be of great importance to the future of the Department's programme, was the beginning of the construction of a long-needed

high-voltage equipment of considerable size, with associated facilities—a project which has been given the name "Atomic-Physics Observatory". The large steel tank with its surrounding building and underground tunnels and vaults resembles an astronomical observatory in outward appearance. The designation "observatory" is not without justification in view of the smallness of the regions of space to the study of which the equipment is dedicated—regions whose remoteness from ordinary dimensions and conceptions of size require astronomical magnitudes for their expression. The construction of the observatory . . . was begun on May 20. The new equipment will consist of a large electrostatic generator and vacuum-tube enclosed in a pear-shaped steel vessel 55 feet high and 37½ feet in diameter at the upper end. Air in the vessel is to be compressed to 50 pounds per square inch for electrical insulation of the generator and tube, which are designed to operate under precise control at potentials exceeding 5,000,000 volts. An underground tunnel-maze and control-room surrounded on all sides by earth for shielding of operators and instruments against X-rays and neutrons has been provided. The new installation . . . embodies, on a moderate but adequate scale, the numerous technical developments looking toward analytical and observations evolved by the Department's studies over many years on the application of high voltages to nuclear physics problems.

As is well known, in the attempts made to determine the nature of the atom, great assistance has been rendered by workers in astrophysics who have been able to find in the stars certain atomic conditions which have been predicted by physicists but which they have not observed on the earth.

A New Series of Articles

Attention is directed to the article in this issue entitled *The Bright Nova of 1860 in the Globular Cluster Messier 80, and its Relation to Supernovae* (p. 69), under the heading "Communications from the David Dunlap Observatory." This is the first of a series of research papers which the JOURNAL plans to print from time to time. They will deal especially with contemporary astronomical problems, and it is hoped they will prove of general interest to amateur as well as professional astronomers.

The more technical research papers from the Observatory will appear in its *Publications*.

C. A. C.

MEETINGS OF THE SOCIETY

AT WINNIPEG

October 13, 1937.—The October "social" of Winnipeg Centre, held in Rupertsland College Hall, October 13th, was an improvement on recent functions in embracing an interesting sketch of the Hayden Planetarium (with slides) by Miss K. St. John. Projections from strip-film built up by Mr. Roy Lind were used. The operation of the 16-faceted apparatus at the Planetarium was quite clearly grasped; also the equipment of the "Sun-Room". The tea-tables were in the hands of Mrs. Darracott and Mrs. G. P. Morse. Attendance 36.

G. P. MORSE, *Secretary.*

AT VICTORIA

November 17, 1937.—The meeting was called to order by President Shaw at 8.10 p.m. at the Y.W.C.A. Parlours. The election of Mr. T. Pepper to membership by the Council was announced. Mr. Shaw gave a brief description of the lunar eclipse which occurred during the evening and night. He then introduced Mr. James Smith who gave a brief talk on the spectroscope and the spectrum. The action of a prism in producing refraction and dispersion of light was explained and its application to the construction of the spectroscope. The laws of spectrum analysis and their use in the study of celestial objects was described.

The secretary then introduced Professor Daniel Buchanan, of the University of British Columbia, who delivered the lecture of the evening "Measuring the Universe". Dean Buchanan began his lecture with a discussion of the fundamental concepts of trigonometry, showing how this system of mensuration could be extended to the determination of astronomical distances. The speaker went on to show how the direct measurement of parallax allowed us to calculate the distances from the earth to the moon and sun. The next step was a discussion of Kepler's studies with the regular polyhedra in his search for a law connecting the various planets with their positions in the solar system. The harmonic law and its application to the determination of planetary distances was demonstrated by the use of Eros as an example.

Leaving the solar system, Professor Buchanan proceeded to discuss stellar distances and the measurements made in our galaxy and in inter-galactic regions. The direct measurement of stellar parallax, that based upon proper-motion data, and finally the use of spectroscopic parallaxes were described in some detail. An excellent presentation of the method of dynamical parallaxes was then given. The speaker concluded with a description of the Period-Luminosity law for Cepheid Variables and its application to the determination of the distances of very remote objects.

After the lecture a brief session for questions was held.

R. M. PETRIE, *Secretary.*

RADIO TALKS OVER CFCT, VICTORIA, B.C.

By W. E. Harper

Exploding Stars

(October 19, 1937)

The somewhat startling title of my subject might call up a vision of a fireworks display at a 24th of May celebration where a projectile is hurled skywards and bursts into many-coloured fragments which slowly fall to earth. My topic has no such association.

Nor is it connected with the so-called "shooting stars". These are small particles like large grains of sand, the remnants of disrupted comets of a by-gone age which, coursing through space, are attracted to the earth. Plunging into our atmosphere at forty miles a second they are literally burned up in one bright flash and filter down to earth as ash.

No, the bodies that explode, or blow up, to use a more accurate term, are real stars, millions of miles in diameter. Our sun is such a star and a few facts regarding it will recall the nature of the bodies that blow up. Its diameter is of the order of a million miles so that it is one-and-one third-million times the size of the earth. Surrounding a more or less solid nucleus of gases under enormous pressure is an atmosphere which becomes more and more rarefied with increasing distance from the centre. The temperature is 6000° at the surface, increasing to millions of degrees at the centre and the whole mass may be thought of as boiling and seething all the time.

Now the millions of little pin-points of light that we call stars are all self-luminous bodies like our own sun. They appear faint simply by reason of their great distances from us and were our sun to be removed to similar distances it would appear no brighter than they do. Indeed, on the average it would appear fainter for while we have stars one-tenth the mass of the sun we have others again with a hundred times its mass and thousands of times its real luminosity.

For many years it has been known that some stars vary in light. These variations are of many kinds. Occasionally what appears to the eye, unaided or with telescope as a single star is a physical double and in certain positions the components will suffer eclipse as they mutually revolve about each other. Others again, through internal causes vary in periods of perhaps a few hours or a few days or a few months. The larger the star the longer in general will be the period of variation.

Then we come to the class to be discussed here in which the star from practical obscurity increases very rapidly to a much higher luminosity and then slowly declines in brightness. These are called new stars, or novae, and the particular title I assigned to them suggests the nature of their variability. They simply blow up in one great splurge and, after a few months or a few years, return to their previous faintness, possibly never to be heard from again.

The subject is timely inasmuch as we have had an unusual number of these

of late. Moreover, in the past few years we have been introduced to a new variety—the supernovae—which outshine the common variety a thousand-fold. Let us study first the ordinary novae and get an idea of how many may be expected.

There are indications that the Chinese recorded one in 2679 B.C., but observations until we come to 134 B.C. are none too definite and may refer to comets. The nova in 134 B.C. was observed, not only in China but throughout Europe and was a factor in deciding Hipparchus to make a catalogue of the stars. In passing, it may be mentioned that some believe that the star of Bethlehem, which guided the wise men of the East to the Christ-child, may have been such a new star, but the record is too meagre and I am not prepared to defend this position. There are about eight or nine well authenticated novae before the modern era of observing them was ushered in on the appearance of the brilliant new star which shone in Cassiopeia in November, 1572. This new star which outshone Venus at her brightest was well observed by Tycho Brahe. It took three months to drop to the first magnitude, after which it faded steadily though it remained a naked-eye object for eighteen months.

Slightly over ninety novae in our own galactic system have been discovered from the date of this outstanding one to the present, if we consider all bright, or faint. Several of them were photographic discoveries, their true nature being brought to light long after they had passed maximum. The present century has been very prolific in new stars, many of which have been unusually bright. In 1901 one flared up in Perseus, in 1912 one in Geminorum, in 1918 one in Aquila, in 1920 one in Cygnus, in 1925 one in the southern hemisphere in Pictor, in 1934 in Herculis and in 1936 in Lacerta. These seven are the bright ones only and, except for Geminorum, they were all brighter than the second magnitude, which is the average brightness of the stars of the Big Dipper.

The number that occur yearly was estimated by Bailey, who counted the number which actually appeared on photographic plates. Examination of 1049 pairs of plates taken at different times revealed 14 novae, of which eight were previously unknown. He considered that these 2098 plates were sufficient to keep a bi-weekly check on the region of sky where novae originate for 1.6 years. Thus nine novae per year was the minimum and, if we allow for failure to record the faint ones, probably two or three times this number would be recorded yearly. In another way he arrived at a similar result. Since for the past 350 years there has been a nova of the 3rd magnitude or brighter on the average every 40 years and since there are 1,000 times as many stars brighter than the ninth magnitude as there are brighter than the third, then the number of novae of 9th magnitude or brighter ought to be $1000/40 = 25$ per year. The recent record number of bright novae would increase this average somewhat.

Exploding Stars II

(November 16, 1937)

Last month I introduced this topic by stating that the stars which are spoken of as "new" stars or "novae" are originally bodies comparable to our own sun. For some reason they start swelling and end up by throwing off a shell of material

in a great explosive outburst. We recognize them first by their marked increase in light, it being not at all uncommon for such a nova to increase its luminosity ten-thousand fold in a few days.

I referred in the last talk to seven bright novae that had occurred since the beginning of the century and if the positions of these be noted it will be found that nearly all of them were close to the plane of the Milky Way. This seems to be a favoured position for novae. It is true there is an odd case of departure from this general rule as to their location but the average galactic latitude of all novae in our Milky Way is less than 3°. It might be thought that this tendency toward the central plane is simply that of the stars in general. An investigation shows, however, that the crowding of the novae to the central plane is more than double that of the stars in general so there must be some particular reason therefor. The reason probably has some connection with nebulous material which is more plentiful towards the centre. It is found that novae in our system occur where ordinary stars seem to be sparse but where there is much nebulous material, either luminous or dark.

In line with this characteristic we find a ready explanation of the non-uniform distribution of novae in galactic longitude. From previous addresses you have learned that while the sun is quite near the central plane of the Milky Way it is off to one side of the central nucleus. Briefly put, the diameter of our disc-like galactic universe is 100,000 light years. The sun is about one-third of the distance from the edge to the centre and a shade to the north of the central plane. Thus as one looks towards the centre of the system he is looking through a greater depth of nebulous material than is found in the opposite direction. Now novae have a tendency to occur in the same general direction as the centre of our stellar system; to be specific, more than half of the ninety discovered in our stellar system are within 30° of the direction of the nucleus. Regions where nebulosity abounds seem to be preferred as the birthplaces of novae.

It is fitting now that we leave our own galaxy and explore other universes to see if they have anything similar. For, though the word universe would seem to be all-inclusive, yet it had become so associated with our own Milky Way or galactic universe—before we knew of the existence of others—that we must recognize the limited application of the word. Our Milky Way universe is like unto a flattened disc much as if two dinner plates were placed face to face. The milky zone of light encircling the sky is simply the suffused glow of myriads of distant stars seen in the direction of the long diameter of the system.

To an outsider away off in space in the plane of the Milky Way our stellar system would appear like a thin lens; if we were viewing it broadside on from a similar great distance it would appear somewhat circular in outline, probably with spiral arms radiating from a central nucleus much as we see in the case of other spiral nebulae. These are now regarded as separate stellar systems consisting of millions of stars whose blended light at the great distances of the nebulae gives the nebulous or fuzzy appearance they present.

The nearest such spiral nebula is the great one in the constellation of Andromeda. It can be seen with the naked eye as a fuzzy ill-defined object. By a

comparison of photographs two new stars were found in it in 1909 and then a great many more in the years 1917 to 1926. Hubble alone discovered 44 during the years 1923-1927 and he estimated that about 30 per year made their appearance in this nebula, occurring more frequently in the nucleus than in the outlying parts.

The average photographic magnitude of the 66 Andromeda novae was 17.2 at maximum. From the form of their light curves with the rapid rise to maximum and slow falling away to extinction there was no doubt as to their nova character. The question arose, though, as to whether these objects were similar to novae found in our own system which rose on the average to second magnitude at maximum. Assuming that they were and that all ordinary novae attain approximately the same real luminosity, then the difference of fifteen magnitudes must be an effect of the greater distance of the Andromeda novae as compared with the average distance of the galactic novae. A difference of 15^m means a 1,000,000-fold difference in luminosity or a 1000-fold difference in distance. This was equivalent to recognizing spirals as island universes, the viewpoint upheld by Curtis. Later evidence from the cepheid variables found in the nebula removed any lingering doubt that the spirals were separate universes of stars. Between this particular spiral, which is our nearest neighbour, and ourselves there is a no-man's land equal to ten times the diameter of either universe.

I pass now to a description of the light curves of ordinary novae both of those found in our own universe and those in other similar spirals. The latter novae are naturally not so well observed as those near at hand but the evidence is that they are of the same general type. The curves show a very rapid rise to maximum followed by a much slower, and in some cases a fitful, decrease of light. A few examples and illustrations will be given. In 1866 a star in Corona Borealis of magnitude 9.5 rose in a couple of days to second magnitude. In the last two hours before maximum on May 12th of that year it increased its brightness by two magnitudes, or more than six-fold. It is now a star of Class M and of its original faintness. Nova Persei 1901 rose from $12^m.8$ to $2^m.7$, an increase in light of 10,000-fold in two days. Its downward trend was marked by oscillations in brightness, but in a month it had dropped from 0^m to 4^m. Nova Aquilae 1918 had been known as a variable star, oscillating in brightness between 10^m and 11^m, for some thirty years. In two days it rose to $-1^m.0$, midway between Vega and Sirius in brightness. It, too, had its ups and downs in brightness as it gradually waned.

In nearly every case immediately after the star has attained its maximum it starts to fade again. This is not always the case however. For Nova Aurigae 1891 there was a long flat maximum or, in other words, the star persisted at maximum light over a period of a few weeks before starting to decline. The same can be said of Nova Herculis 1934, although there was a gradual decrease in the first four months before the big drop came.

The light curves are easy to determine, particularly in recent years where in every country there is a host of amateurs who are only too anxious to have such an object to observe. More and more these light curves recording the changing luminosity of the nova are being found helpful in developing and testing theories

but heretofore main reliance for information as to the physical processes involved has been placed upon the spectrum itself.

Exploding Stars III

(December 21, 1937)

I closed my last talk on these new stars by stating that their rapid light changes are well observed nowadays by amateurs and the resulting light curves are more and more being found helpful in testing theories as to origin of these peculiar objects. Heretofore, main reliance has always been placed upon the spectrum itself for information as to the physical processes involved and it is advisable to outline just what we can learn from this coloured band of light which is produced by the spectroscope.

Light from the dense nucleus of the star shining through its enveloping atmosphere is earmarked in various ways depending upon the physical conditions prevailing in the atmosphere. If the temperature is high, say 10,000° and up, with a corresponding low density, then we will find evidences of the presence of the lighter gases, such as hydrogen and helium. If, on the other hand, the temperature is of the order of 2,000° to 3,000° then at these relatively low temperatures, which can be reproduced in our laboratories, the vapours of the metals and even of their oxides will be recognized as present. Each star carries its own finger print in its spectrum.

Now if the nova is caught on the up grade before it has reached maximum, it will show a spectrum in which there are a limited number of broad, absorption lines mostly characteristic of hydrogen. At maximum, or immediately afterward, a host of additional lines appear, due to atoms in a high state of excitation and which we speak of as ionized. They have in effect been stripped of one or more of their outer electrons. The spectrum at this stage is usually a replica of the outer atmosphere of the sun where the gases are in a highly attenuated condition. The dark lines in the spectrum are simply narrow regions or wave-lengths that have been absorbed by the outer atmosphere of the star and since the gases absorb the identical radiation which they would emit were they at a higher temperature, we thus have a clue to the composition of the atmosphere.

But besides the dark strips where light has been absorbed, we have also strips which are much more intense than the average of the coloured band. These are spoken of as emission bands and are produced by the gases of the atmosphere over the whole surface except the limited region just directly between us and the central nucleus. At first the gases concerned are largely hydrogen but soon nearly all that play a part in absorbing light such as the vapours of iron, titanium, etc., also give rise to these isolated emission bands.

There are thus three distinct portions of the star in so far as its spectrum is affected. There is the dense nucleus, almost like a solid, at a high temperature and which gives the almost continuous background of light. The portion of the atmosphere directly in front of us absorbs light coming from the hotter nucleus beyond it and gives us the absorption strips or lines. The remainder of the

enveloping atmosphere on all sides of this limiting central cylinder, shining with its own light, produces the emission bands.

These features change from day to day. At first the continuous spectrum is about all that can be seen, showing that the hot central nucleus or photosphere, as it is called, dominates everything. As time goes on the continuous spectrum weakens, showing that the photosphere is correspondingly reduced in brightness. Parallel with its diminution in brightness the emission bands become more intense, suggesting that more of the light is then coming from the enveloping atmosphere. A study of the absorption lines and their positions gives us the secret of what is actually taking place.

You have heard in previous talks that if a star is approaching us rapidly, its spectrum lines will not occupy their normal positions but will be displaced in the direction of the shorter wave-lengths, that is to say to the violet end of the spectrum. The greater the shift found, the higher the velocity of the star towards us must be. Now the lines in these so-called novae show that the absorbing vapours are coming towards us with high velocities. The simplest explanation is not that the whole star is coming towards us but that it is expanding rapidly. From a very low velocity of expansion it rapidly speeds up to 100 miles per second and keeps on accelerating until speeds of nearly 2,000 miles per second have been measured before the force of the explosion has been spent.

In a few weeks the star usually becomes too faint to be well observed but there is no great doubt that this outward expansion continues for a considerable time. That being the case, we might expect in due time to see a nebulosity surrounding the star and such indeed has in certain cases been observed. The best example is that of the new star which occurred in the constellation Aquila in June, 1918. A nebulous disk was observed in the following year which continued for several years to grow larger at a uniform rate. Apparently the outward expansional velocity reached a steady state after a few weeks.

One of these new stars, particularly well-observed at our own observatory, flashed out in the constellation Lacerta in June, 1936. The facts, as brought out by an investigation participated in by most of the members of our Observatory staff, are contained in a 50-page Publication of the Observatory which is nearly off the press. At its maximum brightness it equalled the stars of the Dipper in apparent brightness. But it is much farther away than they are and so its real luminosity was much greater than theirs. Its distance from us is such that light requires 2700 years to cross the great chasm separating us. If the sun were set back to that distance the nova, while comparable to it before it started the fireworks, would nevertheless at maximum have outshone our sun 83,200-fold.

The main shell blown off from the star accelerated until a speed of between 1,500 and 1,600 miles per second was attained. Of course it must be remembered that the whole star is not disintegrated in these explosions of ordinary novae; the outer covering is sufficient to cause the great flare up. At maximum the diameter of the main star was 210 times that of our sun; it then rapidly diminished in size while the shells thrown off kept on moving outwards. In the near future we may expect to see with the telescope this nebulous material surrounding the central star which has now resumed its original faintness.

The Royal Astronomical Society of Canada

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